OXYGEN-UPTAKE, SHELL MORPHOLOGY AND DESICCATION OF THE FINGERNAIL CLAM, *SPHAERIUM OCCIDENTALE* PRIME

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INTRODUCTION

According to the contemporary authority, H. B. Herrington (1962), the fingernail clam Sphaerium occidentale Prime "has a preference for, or requires, a habitat that dries up for part of the year." As a lamellibranch clam this species is dependent on an aquatic habitat for its feeding, respiration and growth; yet it characteristically inhabits a temporary aquatic habitat. Questions therefore arise as to what ecological, morphological, or physiological adaptations allow survival of this species during the weeks, or even months, of aestivation.

Inactive clams are generally considered to be essentially independent of their external environment (Ghiretti, 1966). Fischer (1950) believed, with regard to the snail Helix pomatia L., that dormancy encompassed two major factors, desiccation and oxygen consumption. Of the two he considered respiration to play the more important role.

Little attention has been devoted to oxygen consumption of sphaeriids. Exceptions are the investigations of Berg et. al. (1962) on Pisidium casertanum (Poli) and Alimov (1965) on Sphaerium corneum (Linné). Both dealt with oxygen-uptake of active clams. Jatzenko (1928) found Sphaerium corneum capable of withstanding anaerobiasis for one and one-half months.

Juday (1908) discovered Pisidium idahoense Roper living in the bottom of Lake Mendota for three to four months when no oxygen could be detected. Cole (1921) suggested that this species was capable of utilizing minute amounts of oxygen that were liberated during plant decomposition in the profundal habitat.

Understandably few studies on lamellibranch desiccation are available since few clams qualify as aestivators. In addition to Sphaerium occidentale, aestivation has been reported in Sphaerium lacustre (Muller), Pisidium personatum, and Pisidium (casertanum) cinereum (Boycott, 1936). Thomas (1963) provided one of the few investigations on the population dynamics of Sphaerium partumeium (Say) in a semipermanent Michigan pond.

Beginning with the summer of 1960, a study was started in an effort to describe some of the aspects of behavior, desiccation, and oxygen-uptake relative to the aestivation of Sphaerium occidentale. The first phase of the study, the field investigation, attempts to describe the habitat, the distribution of the clams during dormancy, and the structure of the aestivating population. As a foundation for later laboratory studies and pertinent to the desiccation of the sphaeriids, certain characteristics of site preference, in situ water loss, and temperature relationships are

studied.

The second, or laboratory, phase concerns oxygen consumption and desiccation. Oxygen-uptake is measured as a function of size, activity, and temperature in active clams and inactive clams. The findings are related to various parameters of the animals, such as weight, volume, length, height, and relative surface area, which are measured or calculated. The density and distribution of pyrimidal cells in various sized clams is explored.

Experiments to determine the longevity and water loss of clams subjected to four different relative humidities are performed to reveal any possible unique ability of this species to withstand desiccation.

It should be mentioned that, except for the taxonomic and zoogeographic reports, the physiological and ecological literature is rather meager for the North American species of Sphaeriidae. Much of this neglect probably stems from the taxonomic confusion preceding 1962, when Herrington consolidated 128 species, representing three genera, into thirty-four species of two genera. As a result it is necessary to utilize a rather wide spectrum of literature on these molluscs.

FIELD STUDIES

In order to better relate certain physiological aspects of Sphaerium occidentale to its ecology, a study was begun to ascertain some of the characteristics of the natural environment as well as the animal's behavior in response to changes in its habitat.

Selected for the study was a small woodland pond located in Itasca State Park (Clearwater, Becker, and Hubbard Counties), Minnesota. This area approximates the virgin conditions of northwestern Minnesota prior to the disturbances of farming, logging, and grazing. The mixed-type forest covers a topography typical of the northern glaciated areas in being traversed by moraines, pocked by ice-block lakes, and etched with lowlands which have formed numerous bogs and swamps.

During a 1959 summer's residence at the University of Minnesota Forestry and Biological Station, Itasca State Park, the author conducted a survey of the sphaeriid species found in some of the lentic habitats present in the immediate vicinity of the biological station. Specimens were collected, temporarily preserved in alcohol, and then air dried. Subsequent to this treatment, they were submitted to Mr. (Reverend) H. B. Herrington, the contemporary taxonomic authority, for identification. Following is a resumé of the findings:

Lake Itasca (25 Peterson dredgefuls taken in a transect from the 25 foot depth to shoreline)

Sphaerium sulcatum (Lamarck)	5
S. rhomboideum (Say)	1
S. lacustre (Müller)	1
Pisidium compressum Prime	9
P. obtusale C. Pfeiffer	2
P. casertanum (Poli)	2
P. nitidum Jenyns	3
P. walkeri Sterki	1

Edge of Sedge Mat; Floating-Bog Bay; Lake Itasca (non-quantitative)

Pisidium casertanum (Poli)	.80
Pisidium obtusale C. Pfeiffer	1

Twin Lakes Bog; tamarack-alder zone (non-quantitative)

Pisidium casertanum (Poli)	.62

Woodland pools (non-quantitative)

Professor Green Trail

Sphaerium occidentale Prime	6
Sphaerium securis Prime	1

Large Icehouse Pond

Sphaerium partumeium (Say)	.58
Sphaerium occidentale Prime	2

LaSalle Trail

Sphaerium occidentale Prime	132

This simple survey, which was intended to be neither intensive nor comprehensive, reflects only the relative abundance of the various species during the sampling period and gives an approximate indication of their local distribution. Although inadequate as a critical survey, it did aid in the selection of a primary study area.

The LaSalle Trail pond was chosen because it afforded the following advantages: (1) ease in identification of species of clams because of an almost monospecific population (2) isolation, possibly leading to greater genetic homogeneity (3) large population of Sphaerium occidentale.

Description of the Study Site

The study area is located approximately 300 yards southeast of the entrance to the University of Minnesota Forestry and Biological Station, or at a point adjacent to LaSalle Trail approximately 100 yards from the junction of LaSalle Trail with the Park Drive. The small bowl situated on the gently sloping hillside measures approximately 120 feet in diameter. Water from the spring thaw, prolonged rainy periods, and unusually heavy showers is caught in this basin. Although watermark evidence indicated higher water levels, the observed maximum depth was about 40 centimeters.

The pond is located in a forest composed primarily of Tilia americana L., Pinus Strobus L., Populus tremuloides Michx., and Acer saccharum Marsh. Several aspen logs criss-crossed the pool and thereby provided easy access for sampling and collecting. Immediately surrounding and occasionally invading the pond were shrubs, such as Cornus stolonifera Michx.,

Alnus spp., and Fraxinus nigra Marsh. The shade from these woody plants and their annual leaf-fall were responsible to a major degree in characterizing the pond.

Seasonally there is considerable variation in ecological conditions. The pond, being intermittent, reflects the precipitation and drying conditions peculiar to the local weather. However, for the convenience of discussion, the annual cycle can readily be divided into three major aspects: (1) spring-early summer (2) late summer-early fall (3) late fall-winter.

With the thaw of the usual winter snow and the rain characteristic of spring and early summer, the pond increases to its greatest size and depth and assumes its most aquatic nature. The bottom plating of leaves develops a rich microflora and discolors the water a pale brown. Feeding actively are the sphaeriids, which behave similarly to snails. They commonly glide along leaves, sticks, and logs, with the siphons extended and swinging slightly from side to side. Upon occasion the clams will attach to the surface film and move about in this inverted position. Although no detailed food studies were conducted, squashes of fresh clams revealed diatoms, unicellular green algae, detritus, and bacteria in the stomachs. Several observations after dark showed no obvious differences in the number of animals from that

observed in the day.

In association with Sphaerium occidentale during the spring-early summer aspect were a variety of temporary-pond animals. Anostraca, Cladcoera, Conchostraca, and various aquatic insects were common. Aplexa hypnorum (Linnaeus) was frequent in occurrence and an aestivating leech, Haemopsis sp., was occasionally recorded. Various species of oligochaetes were present. Wood ducks were frequently seen on the pool. Rana sylvatica LeConte and Rana pipiens Schreber were common inhabitants; the former used the pool as a breeding site. Urinary bladders of several of the wood frogs were examined and found to contain trematodes belonging to the family Gorgoderidae, which utilizes the sphaeriid clams as intermediate hosts.

With the diminished rainfall, higher temperatures, and increased drying that are associated with late summer and early fall, the pool gradually disappeared, first dividing into small pockets of water, then completely drying. Species of Carex, Veronica, Sium, Mentha, Ranunculus, Equisetum, and Galium, which were either latent or relatively inconspicuous in the spring and early summer aspect, became more numerous and vigorous. Except for the irregular and spotty distribution of these plants, the bowl was essentially devoid of higher vascular plants. Few of the aestivating clams were visible on the

surface. Most were to be found buried several centimeters in the duff and humus. During this period grouse and grouse scrapings were common, and shrews were occasionally observed. Raccoon and deer tracks were in evidence in the deepest depression of the basin and were possibly responsible for some accidental mortality through trampling of the habitat.

In the late fall-winter aspect the pond apparently accumulates little water prior to freeze-up. Although no definitive study was conducted, collecting trips in October and November during the period of 1959-1965 revealed, with one exception, that the pond entered winter either dry or moist, but seldom contained standing water.

Distribution of S. occidentale in the dry pond

During the months of June and July, 1960, the LaSalle Trail pond was mapped to record the summer drying process. Various colored stakes were used to designate the contours formed by the water during the drying succession. A standard meter stick, serving as a depth gauge, was positioned in the deepest area of the pond where it also functioned as the reference point for the measurement of the receding perimeter. The resulting contours and the graphic representation of the rapid disappearance of the pool are shown in Fig. 1.

On 14 June, the pond was 29.5 centimeters in depth and the molluscs were actively utilizing almost the complete body of water. Oxygen determinations and general water chemistry were not attempted. Acidity, as measured colorimetrically by brome thymol blue, remained close to 6.2 during the next several weeks. Temperature relationships were not attempted because of the microstatifications and localized solar heating. However, a three-inch immersion thermometer was used to take temperatures in the shade near the depth meter. The temperature rose from 16.0 on 24 June to 26.0° C. on 9 July 1960. The latter was the highest water temperature recorded and was not unexpected in the shallow (5 cm.) puddle which remained.

As drying continued, small pockets of water remained in the basin. It is interesting to note that in these areas still submerged by several centimeters of water, which is sufficient for sphaeriid movement and feeding, little or no activity was evident. On 15 July the pond finally dried; very few live clams and some empty valves were visible on the substrate surface.

Subsequent to the complete drying a survey was made to determine if the sphaeriids demonstrated any special behavior, such as moving to preferred aestivation sites, or concentrating their numbers in

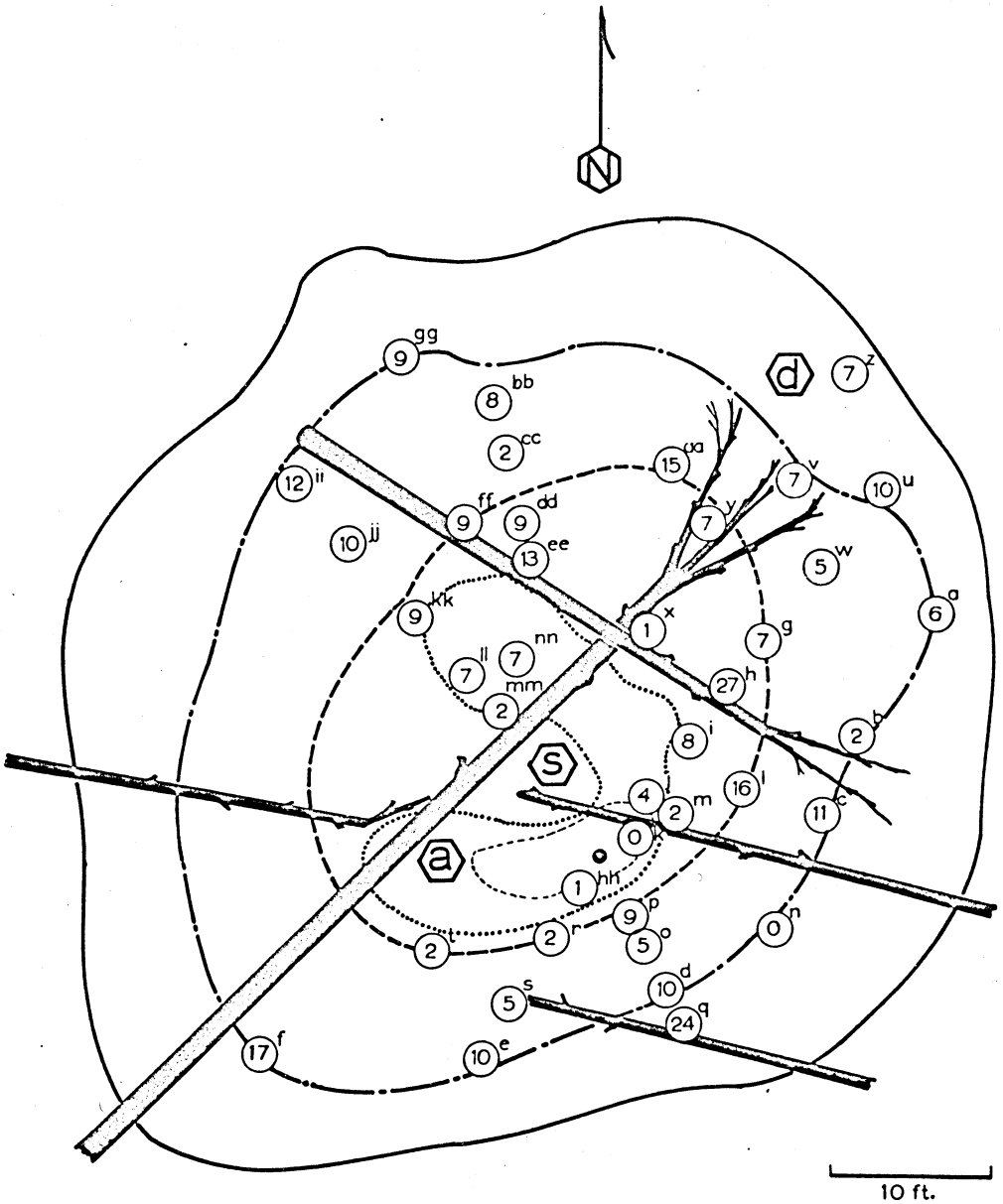

Fig. 1. Distribution and density of aestivating S. occidentale in LaSalle Trail Pond, 13 August 1960.

the remaining aquatic habitat. A metal cylinder 10.5 centimeters in diameter was employed as the sampling device. This was pressed into the substrate to a depth of 10 centimeters and a core of the flocculent, highly organic pool bottom was extracted. A total of 40 samples was taken along the radii formed by the contour stakes and the water gauge. The core was then placed in a white pan and teased apart, exposing the clams. In order to impose some control on the highly-variable technique of searching for the animals, the debris was systematically searched for three minutes after the "last" clam was found. The specimens were then placed in shell vials and transported to the laboratory for measurement.

A dissecting scope and ocular micrometer was used to measure the length of the molluscs. The results of the survey are given in Table 1. In Fig. 3 the sample locations are given as well as the number of clams, 3.0 mm. in length or larger, extracted from the samples. This limitation in size was imposed to preclude the inclusion of freshly released young that were dropped by adults immediately before aestivation. The homogeneity of the study site is evident from the occurrence of only 7 Pisidium sp. compared with a total of 477 Sphaerium occidentale. No other species of the genus Sphaerium were found. In Ontario, Judd (1966) found Pisidium (obtusale Pfeiffer) ventricosum Prime

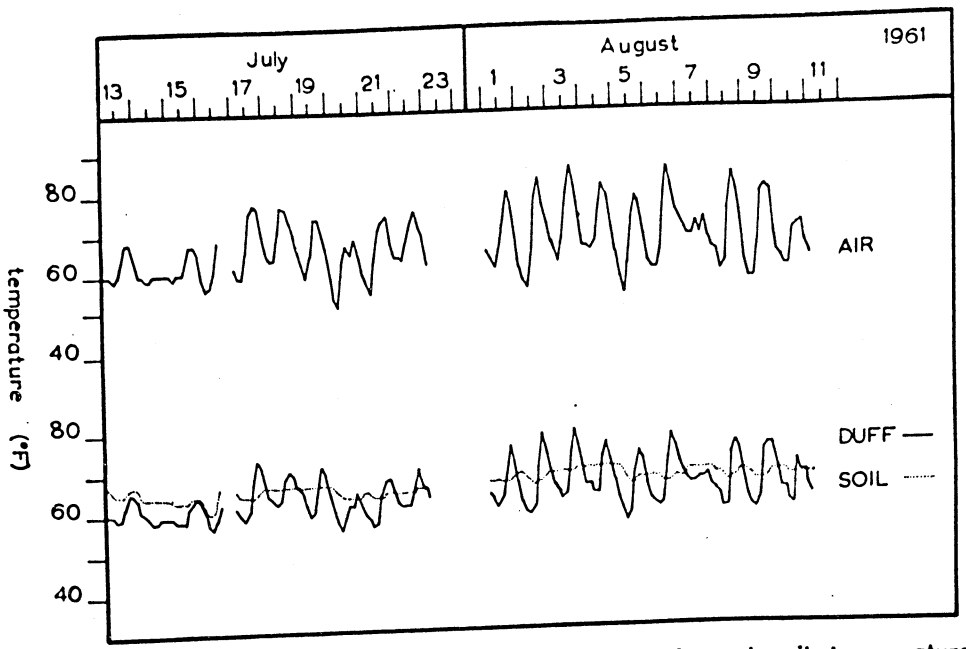

Fig. 2. Thermograph recordings of air, duff, and soil temperatures in the dry LaSalle Trail Pond, summer, 1961.

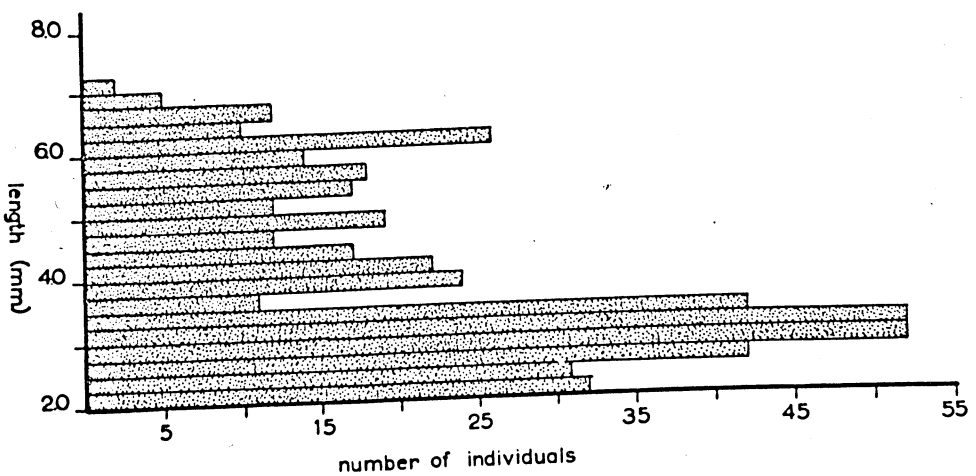

Fig. 3. Size-class structure of the aestivating population of Sphaerium occidentale in LaSalle Trail Pond, 13 August 1960.

in about the same relative abundance, occurring in temporary woodland pools.

Observations on the aestivating clams

During this sampling and in subsequent collecting, it was obvious that the clams tended to aggregate in small depressions, especially if the substrate material was loose. It was common to discover several dozen adult clams in one of these pockets, in addition to numerous young.

The nature of the pond substrate varied somewhat from the center to the periphery. A rather heavy organic mud occurred in the area approximately described by a contour intermediate between those of 9 July and 8 July 1960. Consistently fewer clams were observed in this area and the results of the above samples corroborate this observation somewhat. The remainder of the pond showed a gradual transition from the mud to a highly organic duff and humus mixture. The highest numbers of aestivating clams were characteristically found in the less compacted material.

Viability was not determined on the above samples. However, clams which are dead become opaque and chalky, often gape and disintegrate rapidly, whereas live, moist individuals maintain a translucent appearance that is readily distinguishable. Admittedly this distinction does not provide an accurate index of

viability in the drier sites. It is believed, however, that the distribution shown fairly accurately depicts the population in the pond.

Some of the clams that were collected exhibited a vacuole, or occasionally vacuoles, of air in the mantle cavity. Most frequently this bubble appeared along the ventral margin, but in the more desiccated animals it was sufficently enlarged to occupy most of the mid-ventral area. It was observed that those molluscs situated superficially in the substrate showed bubbles more frequently than those present in the deeper, and more moist, leaf mold.

As previously mentioned, most of the clams bury themselves under debris as the water diminishes, so that very few clams were to be seen on the surface of the dried pond. More frequent were the empty shells, predominantly of the larger clams. However, caution must be admitted in attributing this behavior to the sphaeriids as it is possible that differential predation by birds or other organisms would accomplish the same effect.

Microclimatic temperatures

In the summer of 1961 three thermographs were positioned at the pond in order to measure the temperature of (1) the air, (2) the duff layer, and (3) the soil. The air sensor was suspended from a

low tree about two to three feet from the ground, whereas the duff sensor was placed in and covered with duff. The probe for ground temperature was buried approximately three inches below the surface. All were shaded. Their positions are shown in Fig. 1. Fig. 2 shows graphically the results of the readings, two ten-day periods, one from 13 to 23 July, and the other from 1 to 13 August 1961.

Discussion

Corroborating the findings of Herrington (1962) and Judd (1966) are the results of the pilot survey of the sphaeriids of the Lake Itasca locale. Of the three pools in which S. occidentale was found, two are temporary and the third, namely the Large Icehouse Pond, undergoes some drying although it would be classified as permanent. In both Professor Green Trail Pond and the Large Icehouse Pond other species of the genus Sphaerium are co-inhabitors. Judd (1966) cites S. securis as occurring with S. occidentale, as does Herrington (1962) for S. partumeium. Whether S. occidentale is not competitive in permanent waters with other species of the genus Sphaerium, or if other Sphaerium species are incapable of maintaining themselves in the rigorous environment of the temporary pools, remains an unresolved question regarding the unusual distribution of this species of clam.

That S. occidentale is successful in colonizing temporary ponds is evident from the populations that have been reported. In an Ontario swamp, Herrington (1948) collected 2536 individuals within a six-foot diameter sampling area. While it was not indicated in his data if the smallest size classes were included in the count, dead but intact valves were tallied. Converted to the metric system, this density would approximate 2536 clams in 2.625 square meters, or 966 shells per square meter. In the present study 477 clams were removed from 3462 square centimeters of substrate for a calculated density of 1378 molluscs per square meter. Comparable to this value is the finding of Hunter (1964), in which Sphaerium corneum, a permanent water species, occurred in densities of 1420 animals per square meter in favorable European localities.

The pyramid of size classes with its broad base suggests a stable population. Unfortunately it does not provide an index of absolute chronological age since size is a reflection of duration of active-feeding periods, which are highly variable in an intermittent aquatic habitat. With regard to a related species, Sphaerium solidulum, Foster (1932) suggests that most individuals live less than one year. Herrington (1944) offers evidence that S. occidentale does not attain maximum growth in one year. By means of some crude mass-marking experiments, Herrington

(1948) established that the larger individuals probably have survived two, and some, three winters. Inactive periods are reflected in the markings of the shell (Herrington, 1944, 1948) but the ecology of the individual precludes the use of growth marks in absolute aging studies. In contrast Thomas (1963) found S. partumeium to survive the dry conditions primarily as young animals.

Regardless of the population structure of S. occidentale, its ability to endure a prolonged non-feeding, aestivating period must involve some specialized physiology and ecology. In the pond studied, it is not only possible, but highly probable, that some of the clams entering aestivation in the summer will not be able to feed until the following spring thaw. During this time and dependent on their aestivating site, the clams will be subjected to a variety of temperatures, oxygen tensions, and drying pressures.

In response to the drying of the pond Sphaerium occidentale does not migrate with the diminishing front of water. Instead, the data suggest that the clams are relatively passive. However, they do apparently condense into aggregates in the residual pockets of water, and eventually migrate downward through the porous duff. Of interest is the observation that the smaller clams were often found

somewhat deeper in the same depression than the larger aestivating clams. This tendency can be explained by the comparative ease with which the smaller clams could penetrate the porous duff and humus. Similarly, the relative paucity of individuals in the regions of compacted mud may be explained by the lack of suitable sites or the impenetrability of the barer soil, or possibly by the loss of those organisms at or near the surface to differential predation and exposure.

That the aestivation sites were subjected to considerable drying was demonstrated by air bubbles present in the mantle cavities of many of the clams, particularly those more superficially located in the substrate. The moderating effect of this layer on the impact of temperature is shown in Fig. 2. While not studied, the drying power of the air would be closely correlated with increases in temperature. Obviously the substrate microclimate is of major significance to the survival of this organism.

LABORATORY STUDIES

Field collection of specimens

Collections were made of fingernail clams during the ice-free seasons of 1961-1965. The molluscs were collected by two primary methods depending upon the water conditions in the LaSalle Trail Pond. If water was present, as in late spring and early summer, the bottom debris was picked up and vigorously shaken in a bucket of water. Eventually the surface water was decanted and the denser clams were found concentrated in the bottom of the container from which they were removed by hand. An alternate method of collecting involved dipping with a net made of 1/8 inch screen.

If the pond was dry, as it was frequently in late summer and early fall, the sphaeriids were collected by searching the duff and humus layers, and removed by hand.

The clams were transported to the laboratory in receptacles containing moistened leaves or layers of cloth. During extremely hot weather ice was placed adjacent to the clam container.

It was repeatedly observed that when the dry aestivating clams were placed in the moisture of the transport container, a faint "click", not unlike that produced by a well-known breakfast cereal, was audible. No investigation was made of its origin although its

coincidence with the application of water suggested possibly the rehydration of the dried mucous, shell, or hinge.

Maintenance of cultures

After the field collection and transport, the sphaeriids were placed in a ten-gallon battery jar along with some leaves and debris taken from the pond. Well-water was used in filling the container. Continuous aeration was provided by several airstones from an aquarium pump. The battery jar and aerator were placed in a refrigerated room where the temperature was maintained at 15-18° Centigrade. This temperature approximated that of the clams natural environment in late-spring when they are actively feeding. The tank was continuously illuminated by a 60-watt incandescent bulb located approximately six inches above the tank.

The food of sphaeriids is thought to consist mainly of diatoms, bacteria, yeasts, and probably detritus (Gilmore 1917, Baker 1928, Rodina 1948). Krull (1936) found S. partumeium capable of being grown in water with aged oak leaves. Thomas (1954) successfully used small quantities of strained spinach and liver to which calcium carbonate, magnesium sulfate, and phosphates were added. She was able to grow freshly emerged young to adults repetitively over

several generations.

In the present study a method similar to that of Krull (1936) was used. Bi-weekly additions of leaves from the collecting site as well as rodent food-pellets were made to provide a substrate for bacterial growth. At the same intervals, distilled water was added to replenish the loss by evaporation.

Although clams were maintained in this manner for as long as seven months, there was considerable mortality, particularly among the older clams. Since no definitive studies on weight increase, shell growth, or longevity of individuals was conducted, it is not certain that the conditions were optimal for maintenance and growth. Adult clams, however, were found with marsupial young present at every sampling time.

Physical characteristics of the valves

In order to formulate the pattern of gross body proportions relative to growth and to establish a basis for subsequent oxygen-uptake investigations, measurements were made of the following: length, width and height; total weight and shell weight; volume; shell thickness; distribution and density of the punctae.

All the subsequent measurements were made on the same individual clams. The fifty clams comprising this group were visually sorted into five groups of

approximately equal-sized individuals. The size ranged from the very young, essentially freshly-released animals of approximately 2 mm. in length to the largest individuals in excess of 7 mm. In handling, however, some specimens were lost or damaged so that some dimensions are reported from fewer than fifty clams.

Prior to any measurements the sphaeriids were cleaned with a camel's hair brush to remove any debris adhering to their valves. They were then blotted dry.

Individual methods for the various measurements will be succeeded by the general results and overall discussion.

Length, width, and height of the shell

These dimensions were measured by means of a binocular dissecting scope fitted with a calibrated ocular micrometer. Magnifications of 17 power were used, and measurements were made to the nearest 0.1 of a millimeter.

Length is the maximum distance between the anterior and posterior extremities of the clam. It was measured with the clam on its side.

Width refers to the distance between the greatest lateral curvatures of the valves in the transverse plane. It was measured by viewing the animal from the ventral surface.

Height is the maximum distance from the ventral

border to the dorsal extremity, i.e., the umbonal cap, in a plane at right angles to both the sagittal and transverse ones. It was measured by viewing the animal from the lateral surface.

Total weight and shell weight

All weighings, with the exception of metabolic weight, were made to 0.1 milligram using an analytical balance. The terms are defined below:

Clam, or total weight, is the weight of the complete organism which is blotted or air dried so that no appreciable moisture exists on the surface of the valves.

Shell weight refers to the weight of the shell after drying at 60° C. for at least 24 hours. The soft portions were previously removed by dropping the organism into boiling water and removing the soft body with forceps.

Metabolic weight, is the difference between the shell weight and the total weight; therefore, it is a calculated value.

Volume

Volumes of the clams were determined by water displacement in an instrument of original design (Fig. 4). Construction and operation of the volumeter are described below.

A 1/10 ml. pipette, graduated in 100ths, served

as the measuring device. Animal chambers of various diameters (3-8 mm.) were made of glass and etched with a circular ring near the open end. The opposite end of the chamber was drawn to a taper which fit a plastic-tubing connector extending from the pipette to the animal chamber. A screw-type pipette filler attached to the oral end of the pipette served as the feed mechanism for adjusting the apparatus. The device was supported by a ringstand from which clamps extended to the pipette-filler, pipette, and animal chamber.

Prior to operation, the pipette-filler was screwed-down until the meniscus in the animal chamber was aligned with the reference ring, and the meniscus in the pipette rested near the delivery end of the pipette but in the graduated region. The level of the meniscus was then recorded in microliters. Because the volume between these two starting points is fixed, the addition or removal of water was sometimes necessary to achieve this initial arrangement.

The blotted clam was then carefully slipped into the chamber, the diameter chosen being slightly larger than the greatest dimension of the mollusc. The pipette-filler was then employed to return the meniscus in the animal chamber to the reference ring. After this was done, the volume of the clam was computed by subtracting the original level of the fluid in the pipette from the final level. Volumes were measured

to the nearest microliter (µl).

In operation it was found that a deep animal chamber allowed several organisms to be sequentially measured without requiring anything more than the removal of excess water. However, when it was necessary to account for individual specimens, as in a series of fifty clams, only one mollusc was measured at a time. Removal of the fragile clams was accomplished by first filling the animal chamber to the brim, inverting, and then allowing the organism to settle to the mouth, from which a gentle tap was sufficient to dislodge the fluid and specimen onto a padded receptacle.

Errors arose from several sources. One of these, parallax in viewing the meniscus, was reduced by fitting a sight to the instrument. Another discrepancy resulted from capillarity of the water in the pipette, thereby reducing the assumed constancy of the water column. The addition of a small amount of detergent offset this tendency somewhat, but unless manipulated carefully, tended to form troublesome bubbles. Any bubble, either in the animal chamber or pipette, naturally increased the apparent volume of the water and produced inaccurate results.

The accuracy of the instrument was tested by introducing with a lambda pipette known, small quantities of water and measuring the resulting

increase in volume. Each volume was tested three times and the mean used for error analysis. The percent error ranged from -4.7% to +3.3%. In the range (10-50 µl) of samples tested, the mean error was slightly less than 3.0 percent.

With the 50-clam series, all volume determinations were made three times and the mean value, rounded to the nearest microliter, was used. No individuals below 10 microliters were measured.

Shell thickness

After the foregoing determinations were made, and the fleshy parts removed for dry shell weighing, one valve was reserved for shell thickness studies. A precision 25 mm. micrometer, calibrated in 1 micron increments, was used to measure small (1 mm^2) fragments of the shell removed from various areas of the valve.

In the animals of the 25-80 mg. weight class, three sites, namely the umbonal, middle, and marginal areas were sampled. In the 10-23 mg. group, only the umbonal and marginal areas were sampled, and in those specimens below 5 mg. weight, only a single sample was feasible.

All fragments were removed from a transect extending in a line from the umbone to the center of the ventral margin. Umbonal samples were taken from or very near the nepionic cap. The marginal specimen

was removed near the edge of the valve but above the marginal thickening, a rim of thickened shell extending from the pallial line to the actual margin. The middle sample was taken midway between the two.

In each case the excised portion of shell was placed on the micrometer spindle and the spindle adjusted until sustained resistance was met. Micrometer readings were converted to the nearest 10 microns or 0.01 mm. value.

Distribution and density of punctae

The remaining dry valve of each clam was studied for the distribution and density of punctae. Punctae are the periostracal terminations of specialized mantle cells.

Specimens, from the same fields described for shell thickness, were removed, mounted in piccolyte, and observed at 100X magnification under the compound microscope. The microscope was fitted with a Whipple Square, the subquadrats of which measured 0.09 mm. on a side. The punctae enclosed in ten separate quadrats were separately recorded, and the average value calculated.

Results

The results of the measurements on length, height, width, clam weight, shell weight and volume are presented in Table 2. The findings are arranged in

groups representing various size classes. From these data the relationship of one measurement to another was compared.

Fig. 6 gives the scatter diagram of height compared with length. In Fig. 7 width is plotted against length, and in Fig. 8 clam weight and shell weight are similarly treated. Volume is plotted against clam weight in Fig. 10.

From the apparently linear relationships involved, regression lines were calculated using the least squares method described by Croxton (1953).

Below is a summary of the estimating equations, standard errors, and coefficients of correlation for the various measurements of the sphaeriids:

Number	Measurements	Equation	Standard Error of Estimate	Correlation Coefficient
38 clams	Clam Wt=X Volume=Y	Y=.861X+.886	2.364	0.982
47 clams	Clam Wt=X Shell Wt=Y	Y=.212X+.245	0.385	0.995
40 clams	Length=X Width=Y	Y=.556X+.162	0.405	0.654
50 clams	Length=X Height=Y	Y=.829X-.092	0.180	0.982

The data from the shell thickness determinations and punctae densities are presented in Table 3 and shown graphically in Fig. 5. Following are the mean

thicknesses for the various size groups of clams and the different regions sampled. Included are the ranges observed.

Mean Shell Thickness and Range (mm.)			
Group	Umbone	Mid	Margin
A	.050 (.04-.06)	.071 (.06-.08)	.123 (.10-.16)
B	.043 (.03-.05)	.061 (.05-.07)	.094 (.09-.11)
C	.042 (.04-.05)	.053 (.04-.06)	.091 (.08-.10)
D	.032 (.03-.04)	----------	.060 (.05-.07)
Y	.019 (.01-.02)	----------	----------

Below is a similar summary for punctae density in the various parts of the shell of different size classes of clams. The averages shown are calculated from the mean densities of punctae per ten sampling fields of 0.09 mm^2 per clam. The observed ranges are also included.

Mean Number of Punctae per .09 mm^2			
Group	Umbone	Mid	Margin
A	17.35 (10-24)	8.31 (4-12)	2.49 (0-6)
B	17.76 (12-23)	6.78 (3-13)	2.36 (0-5)
C	16.89 (10-24)	5.16 (2-10)	1.81 (0-5)
D	13.25 (9-19)	----------	2.82 (0-6)
Y	7.01 (5-10)	----------	----------

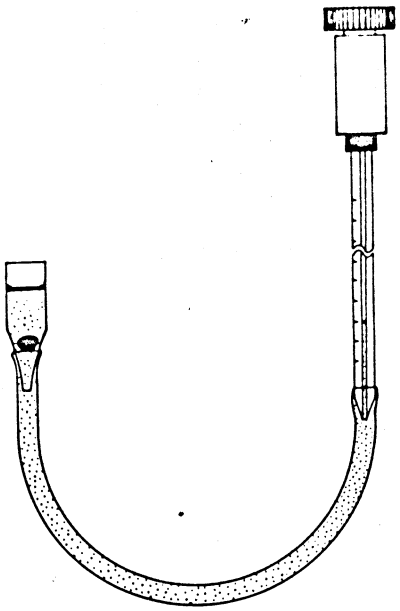

Fig. 4. Diagram of volumeter

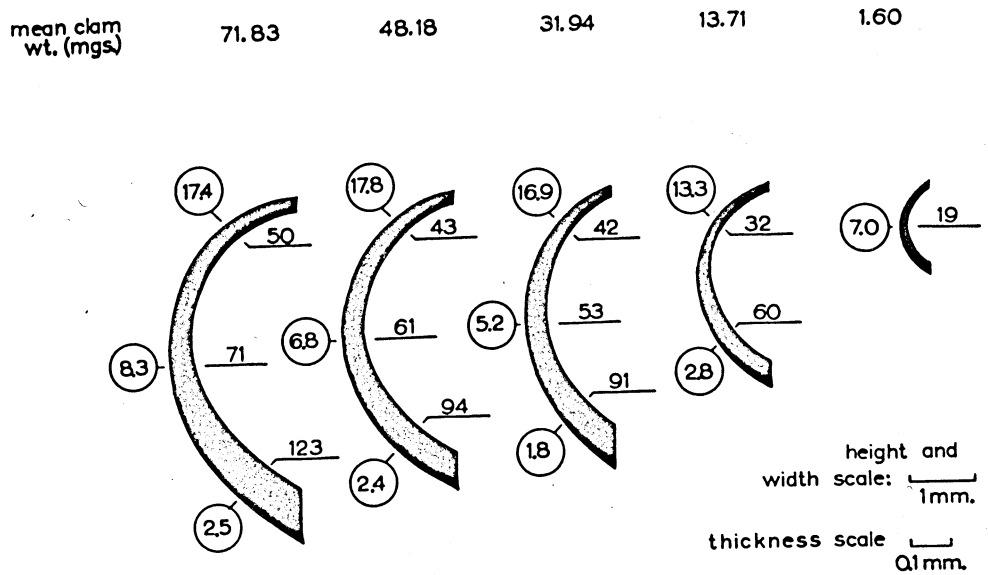

Fig. 5. Relationship of density of punctae to shell thickness in clams of various sizes. ENCIRCLED VALUES = NUMBER OF PUNCTAE / 0.09 MM.^{2}, UNDERLINED VALUES = SHELL THICKNESS (MICRA).

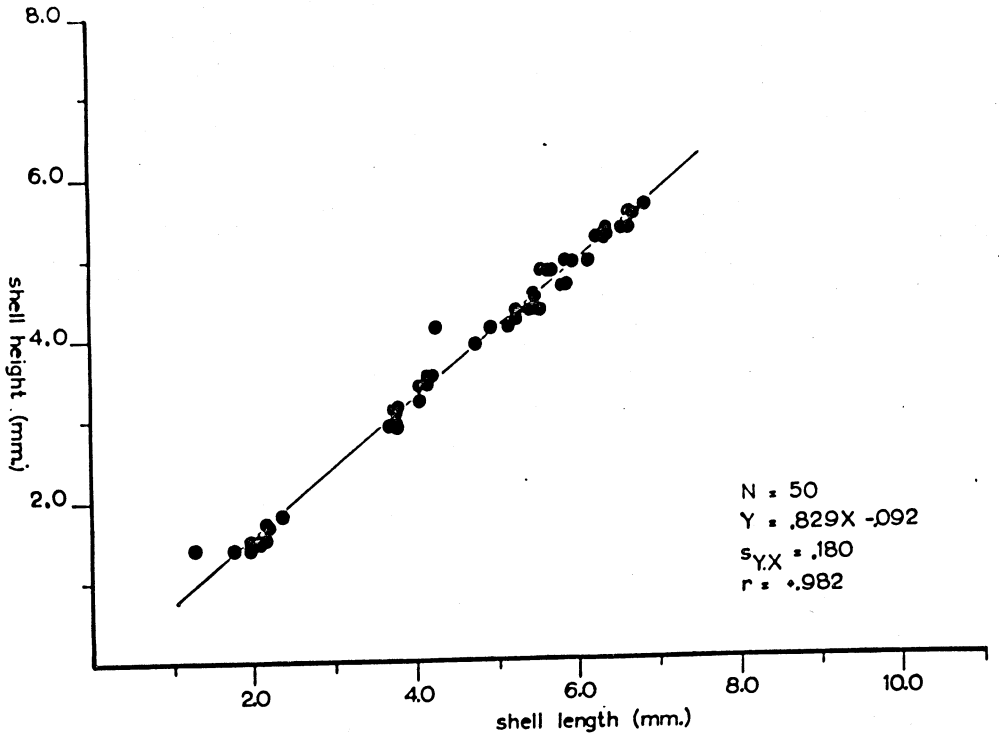

Fig. 6. Relationship of shell height to shell length.

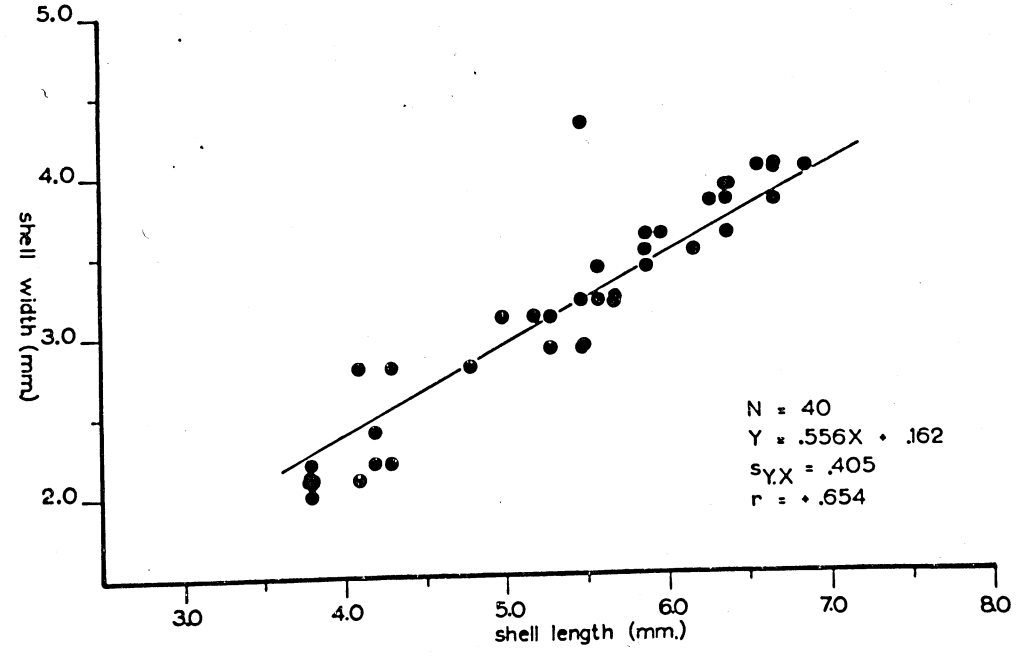

Fig. 7. Relationship of shell width to shell length.

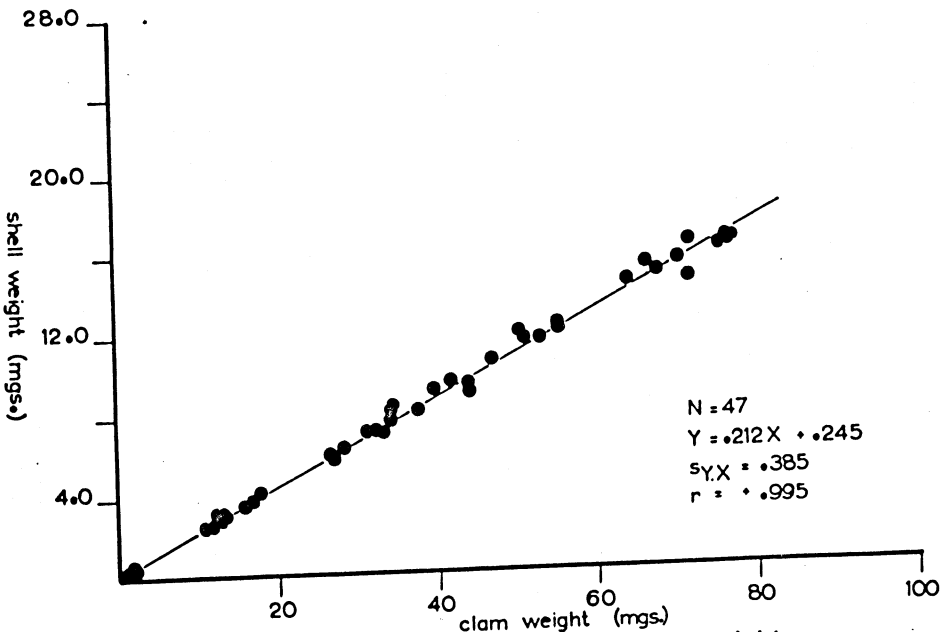

Fig. 8. Relationship of shell weight to clam weight.

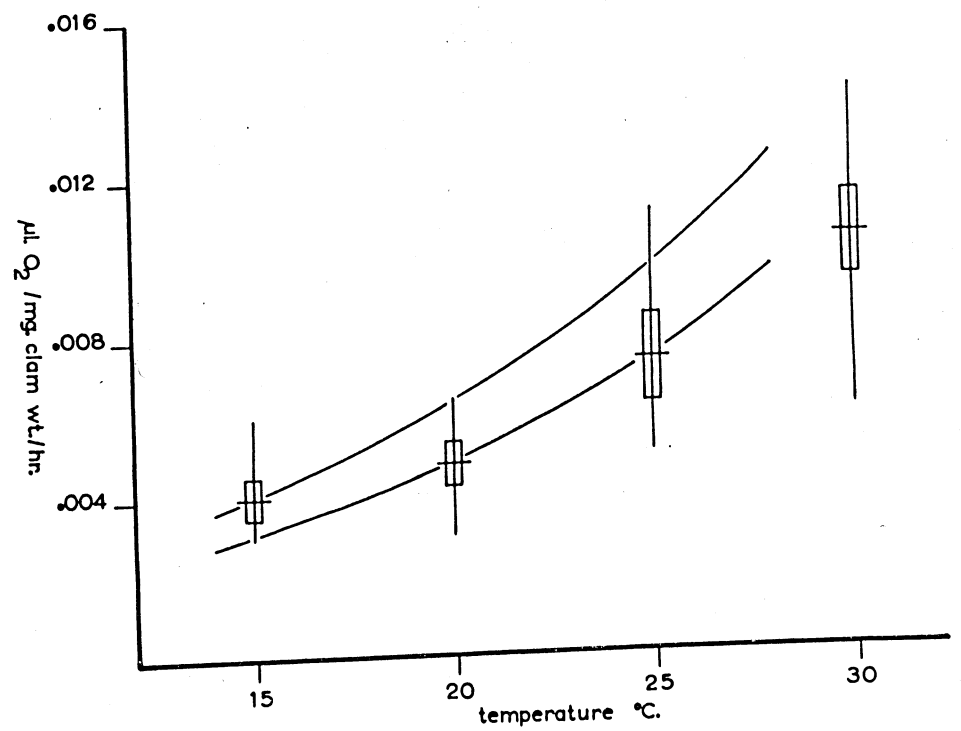

Fig. 9. Oxygen-uptake of moist surface, inactive individuals of S. occidentale at various temperatures (Respirometer B).

SYMBOLS - VERTICAL LINE = RANGE, HORIZONTAL LINE = MEAN, RECTANGLE = ± 2 STANDARD ERRORS, CURVED LINES = KROGH'S CURVE FITTED AT 15° AND 25° C.

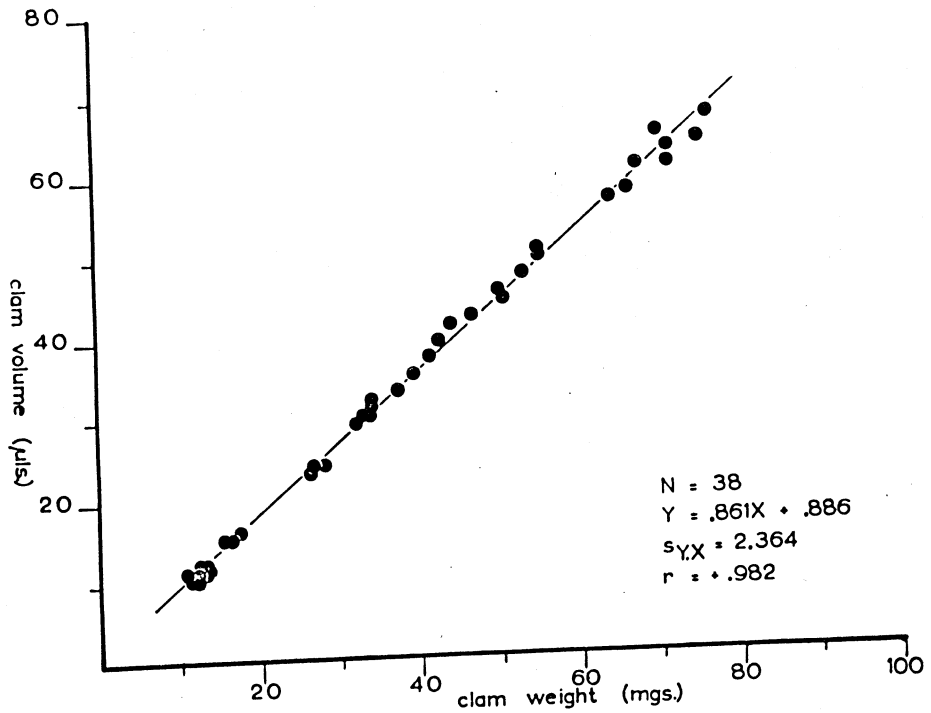

Fig. 10. Relationship of clam volume to clam weight.

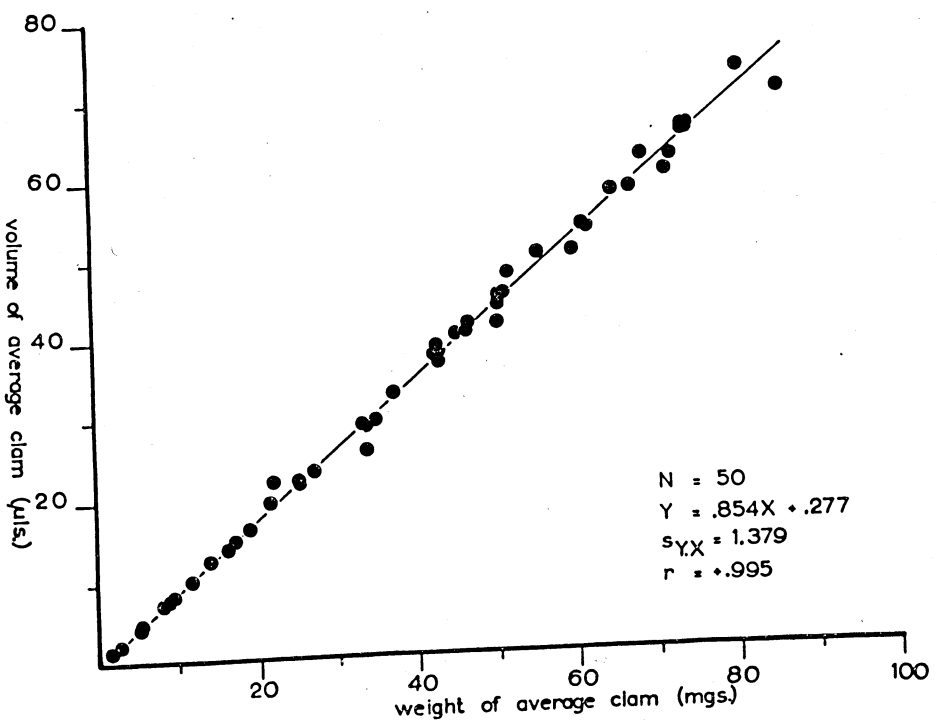

Fig. 11. Relationship of volume to weight in groups of clams.

Shell thickness varies according to the size of the organism and the region of the valve sampled. The umbone is the thinnest site, regardless of the size of the organism, and the margin is the thickest. While not shown in the above data and not intentionally included in the marginal samples, a rim of thickened shell extends around the perimeter of the valve. The width of the rim coincides with the area between the pallial line and the free margin. Apparently as the clam grows, a thin layer of nacre is deposited along the inner surface of the valve from the umbone to the pallial line. However, the greatest thickness is produced on the rim, although this area was not sampled. The relative thickness of the umbonal areas compared to those of the marginal samples seems to approach a ratio of 1:2.

The distribution and density of punctae vary according to the size of the clam and the region of the valve. However, the relationship is inverse to that of shell thickness. In each case the umbone was found to possess the greatest density of punctae and the margin the least. The larger clams, however, possess more punctae per unit of umbonal area than the smaller ones. This increase in density is most pronounced in the early growth stages but progressively seems to migrate toward the margin in all sizes.

From the height of concentration in the umbonal

region, the punctae diminish in numbers toward the margin. Essentially growth of the shell, which occurs in several planes, seems to produce a dilution of numbers toward the rim, until at the thickened rim, there are few, or none, present. No punctae were observed in the rim, and in the area dorsal to the rim (margin) there were few to be found. Those present were often clumped and their canals through the shell material were commonly not perpendicular to the periostracum.

Discussion

Wilbur and Owen (1964) summarize the voluminous literature on molluscan growth, including allometric and isometric forms, and absolute and relative types. The foregoing study on Sphaerium occidentale would categorically be called a relative growth investigation because ages were not included. The study revealed that the various measurements of clam weight, shell weight, volume, and certain dimensions of the shell, namely length and height, are related in a linear, proportionate manner: they are isometric. The relationship was less exact for shell width.

Thomas (1965) followed absolute growth, as measured by length and height changes, in a laboratory and a field population of Sphaerium partumeium. Both groups of specimens showed the more typical sigmoid

growth curve. Length to height ratios remained constant after the third or fourth week (2-3 mm. long) until the conclusion of the experiment, when the adults achieved a length of 5-7 mm. Although width was not measured, Thomas (1965) suggests that for Sphaerium partumeium this dimension would change markedly during the rapid growth phase. Alimov (1965) found the weight-length relation of the European species, Sphaerium corneum, to be expressed by the formula $P = aL^b$, where P is the weight, b is the length and a and b are the constants 0.0002 and 3.23 respectively. Nomura (1926) found height = .348 X width$^{1.26}$ and weight = .147 X width$^{3.22}$ for Sphaerium heterodon.

The progressive thickening of the shell of Sphaerium occidentale with increasing animal size and distance from the umbone has already been described. No similar studies apparently exist. Of particular interest, however, is the inverse correlation between shell thickness and punctae density.

Many, if not all, Sphaeriidae possess small punctae on the shell. In the descriptive literature these spots are referred to as punctae although microscopically they are the periostracal terminations, or the tubes within the calcareous layers, formed by the pyramidal cells. Pyramidal cells are specialized mantle cells which project into or through the carbonate shell. Their function is speculative.

Taylor (1900) believed the "periostracal hairs" to possibly function as hygroscopic elements, similar to a counterpart in certain gastropods. The same author cites their preponderance in the umbonal region.

Schroder (1907) first studied pyramidal cells in detail in the clam Sphaerium (Musculium) lacustre. He originally believed these specialized cells to possibly function in secretion but later rejected this hypothesis because the cells were not located at the edge of the mantle. He then conceived of them as possibly sensory cells.

Rosso (1954) studied these cells in the young and extramarsupial embryos of Sphaerium (Musculium) transversum. The smallest individual with detectable pyramidal cells was 1.29 by 1.02 mm., and the largest individual without these cells was 1.63 by 1.25 mm. In the same study Rosso found a prismatic layer, which was inextensively developed and therefore previously overlooked in the Sphaeriidae. He suggests that the pyramidal cells may be associated with the secretion of the prismatic layer although such a function does not agree with the production of this layer as now known from other molluscs.

It seems difficult to reconcile punctae or pyramidal cells functioning in shell maintenance. Shell deposition seems to occur in their absence and the areas of highest punctae density are not regions

of great shell reorganization. While a sensory function is plausible, another function will be proposed in the next section.

OXYGEN-UPTAKE

The subsequent studies on Sphaerium occidentale were designed to investigate oxygen consumption under various conditions of activity and inactivity simulating some of the circumstances to which the animal is subjected in the natural environment. Very few studies on aerobic respiration have been conducted on the sphaeriids but the works of Berg et. al. (1962) and Alimov (1965) are notable exceptions. Anerobic respiration in certain species has been studied by Jatzenko (1928) and indirectly by Cole (1921). Because of the lack of background information, the principles of general molluscan respiration, accumulated from a spectrum of taxonomic groups, will necessarily be cited.

Ghiretti (1966) states "even under constant external conditions, the oxygen utilization of a given specimen of a bivalve species is extremely variable." Variation among and between species is great. The complexity is presumably related to the interworking of intrinsic and extrinsic factors which necessitate utilizing animals of the same age, sex, body weight, and physiological state, as well as the employment of closely-controlled experimental conditions.

Sexual distinctions are perhaps not pertinent to a study of sphaeriids because Odhner (1951) and

Thomas (1959) demonstrated them to be self-fertilizing. Coe (1943) classifies them as functional hermaphrodites. However, other factors are probably significant.

Zeuthen (1953) and von Brand et. al. (1948) have studied the relationship between body size and surface area relative to oxygen-uptake. Seasonal variations were found to exist in snails (Berg and Ockelmann, 1959) and in Sphaerium (Alimov, 1965). In addition to the classic paper of Krogh (1914), von Brand et. al. (1948) and Berg and Ockelmann (1959) have investigated the influence of temperature on a variety of molluscs. Oxygen-uptake in response to salinity was studied by Lumbye and Lumbye (1965) while Cheatum (1934), Berg and Ockelmann (1959), and Van Dam (1954) have dealt with the effect of oxygen tensions. The papers of Berg et. al. (1958), Berg and Ockelmann (1959), Lumbye and Lumbye (1965), and von Brand et. al. (1957) establish, in certain snails, the importance of starvation on oxygen consumption.

While the preceding factors are important in molluscan physiology, the variability between and within species precludes their direct application to Sphaeriids. In the succeeding experiments an attempt was made to define, standardize, and control these variables.

Microrespirometers

Two types of respirometers, each designed for somewhat different purposes, were employed in the oxygen-uptake experiments. Both instruments utilize a closed-system design incorporating a compensation chamber that practically eliminates fluctuations in atmospheric temperature and pressure. This principle was first introduced by Winterstein (1912) and has been variously modified. These instruments are slight modifications of previously reported models and all were constructed in the laboratory workshop except for several glass components.

Respirometer A

The first model was patterned after the basic instruments of Scholander (1942) and Scholander and Edwards (1942). It is diagrammed in Fig. 12. It incorporates two distinctive features: (a) an intra-chamber stirrer for equilibrating the gaseous and liquid phases and (b) a micrometer feed for replacing the volume lost in oxygen-uptake and carbon dioxide absorption. The principal advantage of the latter characteristic is that, unlike the manometric instruments, the volumetric-adjustment mechanism does not require that the volumes of the respirometer be known. Scholander (1942) cites the additional advantage of working at constant pressure especially in the presence of quantities of liquids.

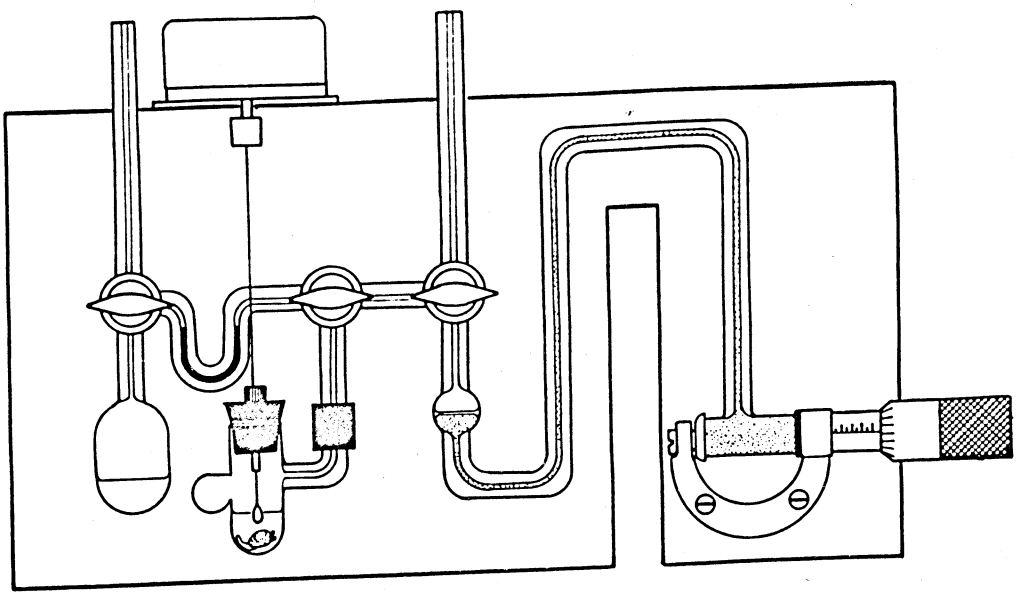

Fig. 12 Diagram of Respirometer A

(modified after Scholander [1942] and Scholander and Edwards [1942])

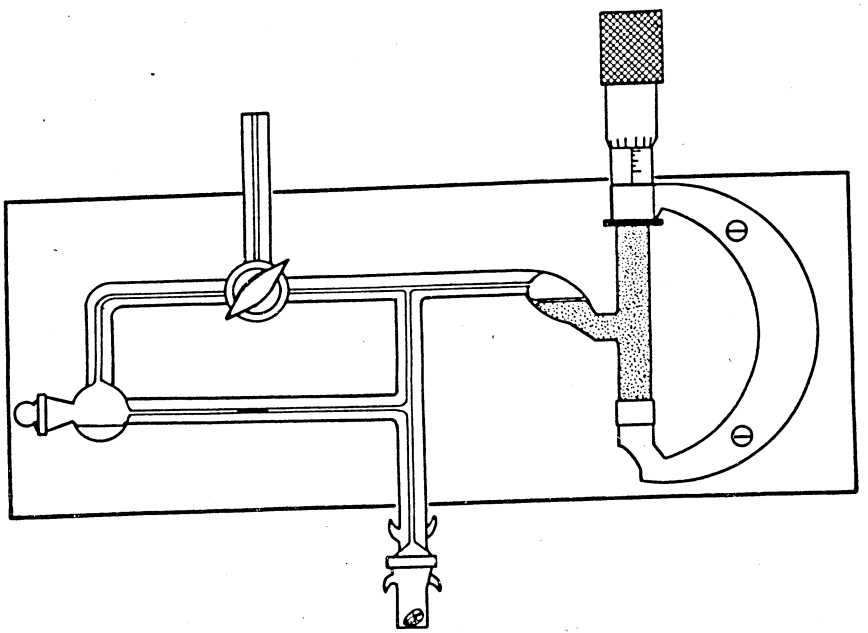

Fig. 13 Diagram of Respirometer B

(modified after Scholander [1942])

Basically the respirometer gas-train is 3 three-way Pyrex stopcocks, 1 mm. bore, united with a mercury reservoir which is controlled by the graduated displacement of a micrometer spindle. To the lower vertical arm of the left stopcock a thin-walled glass cylinder, approximately 1 inch in diameter and 1½ inches in height, was fused; this bubble functions as the compensation chamber. The upper vertical arm was not altered but left to project above the surface of the water bath. The lateral arm of the left stopcock was bent into an open "U" to form a manometer. The middle stopcock, arms shortened, were placed in the "T" position, and served to attach the animal chamber to the train. The third stopcock in the sequence is a mirror image of the first in that its upper vertical arm was left to project above the water surface. Attached to the lower vertical arm was a J-shaped capillary tube. A reservoir was constructed near the stopcock junction. At the opposite end, the capillary tube was fused to a 1-inch length of glass, one end of which was fire rounded, and the other cut and ground square. This chamber was fitted into the spindle gap of the micrometer. Joints between the various glass segments were connected through the use of ½-inch plastic (Tygon) sleeves. The whole apparatus, padded by plastic collars, was mounted on a ¼-inch aluminum-alloy backing. Anchors of wire passed over the plastic

sleeves and fastened to the backing.

Bolted to the frame was a 1-inch standard machinists micrometer, calibrated to 1/10,000 of an inch. While the ¼-inch diameter spindle was unmodified, the anvil was removed and its aperture threaded. A stiff rubber disc, 1/16-inch thick, served as a gasket for the spindle reservoir. A hole, somewhat less in diameter than the spindle, was drilled in the disc, after it had been frozen by immersion in an acetone-alcohol-dry ice mixture. Terminally the anvil screw was provided with a padded, dish-shaped cap which cups the closed end of the reservoir. By adjusting this screw it was possible to press the reservoir against the gasket and spindle mount to produce a leakproof seal. To guard against bumping the projecting micrometer handle and to facilitate handling of the instrument, a 3/8-inch aluminum bar was bolted to the right side of the backing.

Prior to use the compensation chamber was partly filled with distilled water by alternately heating and cooling the bubble while introducing water into the stem opening. The manometer was partly filled with a 0.5% solution of a commercial wetting agent, Turgitol, to which some acid fuchsin dye was added. A plastic scale attached to the frame behind the left arm of the manometer provided a reference for the initial liquid level, or zero point. Mercury was added to the

mercury reservoir, excluding all air, to approximately the half-way level. Several drops of water were sucked-in to cover the mercury in order to reduce the possibility of heavy metal contamination. The stop-cocks, gasket and spindle were heavily greased with silicone grease to seal them against leakage. In order to prevent the entry of dust and water, each of the capillary uprights was capped with a small vial.

Animal chambers were constructed of glass in the form shown in Fig. 12. The capillary sidearm was attached to the vertical arm of the middle stopcock by means of a rubber collar. The animal or animals were placed in the main cylinder to which about 1.0 ml. of water (distilled) was added. Five percent potassium hydroxide was used to saturate a loop of filter paper for the carbon dioxide absorbant, and this was stuck into the side chamber. Scholander and Edwards (1942) caution against using filter paper moistened with lye as they found an "appreciable amount" of ammonia evolved by this method. As an absorbant, these workers preferred Ascarite; however, for some inexplicable reason, the results in the present study were enigmatic when Ascarite was used, and it was found to be much less convenient to handle than the hydroxide.

The basic design of the respirometer (Scholander, 1942) was modified by Scholander and Edwards (1942) to accommodate a stirrer for use in measuring the oxygen-

uptake of aquatic organism. In the present apparatus a similar device was installed by mounting two brackets near the top of the aluminum backing between the manometer and the middle stopcock. The horizontal arms of the brackets, projecting forward, were longitudinally slotted to accept a plate on which a hysteresis motor (Hansen, 600 rpm) was fastened. This plate also was slotted in order to accept wing-nut bolts from the brackets. By making both sets of slots oversize, it was possible to slide the motor over a rather large area, aligning it with the respiration chamber, prior to tightening the wing-nuts.

The shaft of the motor was fitted with a brass chuck, provided with opposing set-screws, for clamping the stirrer to the motor. Stirrers were constructed from over-pulled nichrome wire (size 24), looped in one end to form a paddle. When household cement was placed in the loop and allowed to dry, the effectiveness of the paddle was increased. The chuck was adjusted so that approximately half of the blade was submerged in the water of the respiration chamber.

Whereas Scholander and Edwards (1942) utilized an agar bearing for entry of the stirrer into the animal chamber, this method met with limited success due to inability to keep the stirrer wire straight and a resultant pumping action of the bearing. Consequently a bearing of original design was employed.

Basically it is two flat-faced screws with a 1/16-inch hole drilled through each. The flat faces of the screws are brought together by an aluminum collar tapped to the screw thread-size. All threads and flat surfaces are heavily greased with silicone grease. The actual seal is produced by a disc or two of thin rubber, such as that used in rubber gloves, which are sandwiched between the flat faces of the screws. A tapered shank on the lower screw inserts into a perforated rubber stopper, which then seats into the respiration chamber.

The apparatus with the exception of the micrometer bracket was suspended in a constant-temperature bath to a depth sufficient to cover the stopcocks. For this purpose a standard 15-gallon wash boiler was utilized. Two "portholes" were cut and plexiglass bolted to the sides to provide windows for observation of the manometer, animals, and equipment. A propellor-type stirrer provided circulation which was enhanced by the rounded ends of the tank. A partially uncoiled "coffee-up heater" was found to be an excellent heating element because of its low initial and residual heat capacity. A mercury-to-wire thermoswitch (Model QE-1008, Philadelphia Thermometer Company) controlled, via a relay circuit, the heating cycle. Cooling was effected either by a cooling coil through which tap water was circulated, or through a standard refrigeration coil

placed in an outer water jacket. A wooden box in which the water bath was placed, functioned as an effective insulator. Temperature was controlled to .05° C., the limit imposed by the thermoswitch.

Respirometer B

The second microrespirometer employed in this series of experiments was a modification of the instrument described by Scholander (1942). It is diagrammed in Fig. 13. The chief advantages of this model are: (a) increased sensitivity through the reduction in volumes and (b) total submersion of all quantities of gas.

In contrast to the original linear model cited by Scholander, a 1 mm. bore capillary three-way stopcock was fused into the line in such a manner as to bridge the manometer. It alone connected or closed the respirometer train to the external atmosphere. Also ground-glass joints at the animal chamber and the compensation chamber minimized slippage and creep.

The micrometer used was a 2-inch machinists model, readable to 0.0001 inch. The original 0.25 inch diameter spindle was precision ground to 0.10 inch. As a result, a 0.0001 inch movement realized a calculated 0.012 µl volume displacement. Tests, using water displacement in a fine pipette, agreed exactly with the calculated values.

A drop of 10% Turgitol solution, stained with some acid fuchsin, served as the indicator fluid. Behind the manometer, which had a bore of .25 inch, a plastic reference scale was cemented to the backing.

A loose coil of filter paper, saturated in 5% KOH, served as the carbon dioxide absorbant. Placed in the male part of the ground joint, it was blocked from contaminating the animal chamber by the grease barrier of the fittings. Operation, temperature control, and maintenance were essentially identical to that for Respirometer A.

General procedures in respirometry

Because many of the procedures were routine for almost all of the following experiments, these practices are described below. Exceptions or variations are discussed under the appropriate specific experiments.

Clams were conditioned for at least three days in an aerated aquarium held at $\pm 2^{\circ}$ C. of the experimental temperature. A wire loop was used for handling the clams. Before being placed in the respirometers they were cleaned with a camel's hair brush to remove detritus and mucous. The respirometer containing the organism(s) was allowed at least one hour for temperature adjustment. Temperature was maintained at $\pm .05^{\circ}$ C. of the setting. After the experiment the clams were blotted dry, weighed to the nearest one-tenth of a

milligram on an analytical balance, and the volume determined by the method described earlier.

Frequent blanks, i.e., runs identical to the experimental except without an animal, were made to determine the instrumental error. Generally blanks occurred in the same direction (negative), i.e., the gas volume was reduced, but occasionally were the opposite (positive), i.e., the gas volume being expanded. In each case the average blank value was zero or negative and therefore was subtracted from the experimental values in a given series at a specified temperature.

All gas volumes, including blank and experimental values, were converted to standard conditions by the use of conversion tables (Hodgman, 1957). Dependent upon the purposes and problems of a given experiment, oxygen consumption is expressed variously. Most commonly, however, uptake is given as μl. O_2/mg. clam wt./hr.

OXYGEN-UPTAKE OF ACTIVE CLAMS

Respirometer A

This instrument, possessing an intrachamber stirrer, was employed so that the gases in solution and out would be in equilibrium. Individuals were run in 1 milliliter of distilled water, the stirrer being operative during the thermal adjustment period.

Active clams as defined herein are those animals which are siphoning, protruding the foot, or showing locomotion. The stirrer had an inhibiting effect on active movement. This fact, combined with the unpredictable periodicity of the clams, increased the difficulty in measuring oxygen-uptake of the sphaeriid clams in their greatest activity. However, it was found that by using clams which were active in the holding tank, they often maintained this state in the respirometer.

Timing began after an organism showed sustained activity for at least fifteen minutes. Zeroing intervals and lengths of the runs were necessarily highly variable.

Following is a summary of the individual number of experiments, the temperature range, range in clam weights, and average clam weight.

Number	Mean Duration (hrs.)	Temperature °C	Mean Clam Wt. (mgs)
13	1.0	30 (29.60-29.80)	58.54 (37.0-77.2)
17	1.1	25 (24.75-25.01)	55.82 (40.8-80.3)
15	1.9	20 (19.35-20.49)	47.79 (38.5-71.0)
15	1.8	15 (14.75-15.20)	50.76 (31.0-73.1)

Below is a summary of the blank runs that were interspersed between the experimental runs.

Number	Mean Duration (hrs.)	Temperature Range	Mean µl O_2 per hr.	Range
16	3.69	29.50-29.80	-.191	+.365 to -.508
13	4.46	24.75-25.28	-.026	+.137 to -.330
12	4.56	19.20-20.49	-.184	+.105 to -.481
11	5.23	14.75-16.00	-.130	.000 to -.230

Subsequent to the experiments, these clams were weighed, dried for 3 days at 60° C., and reweighed to determine the water content of the animals.

Results of the experiments appear in Tables 4-7 and appear in graphic form in Fig. 14.

Respirometer B

The obvious inhibition of active movements of the clams by the stirrer was overcome by using the smaller, more sensitive instrument, Respirometer B.

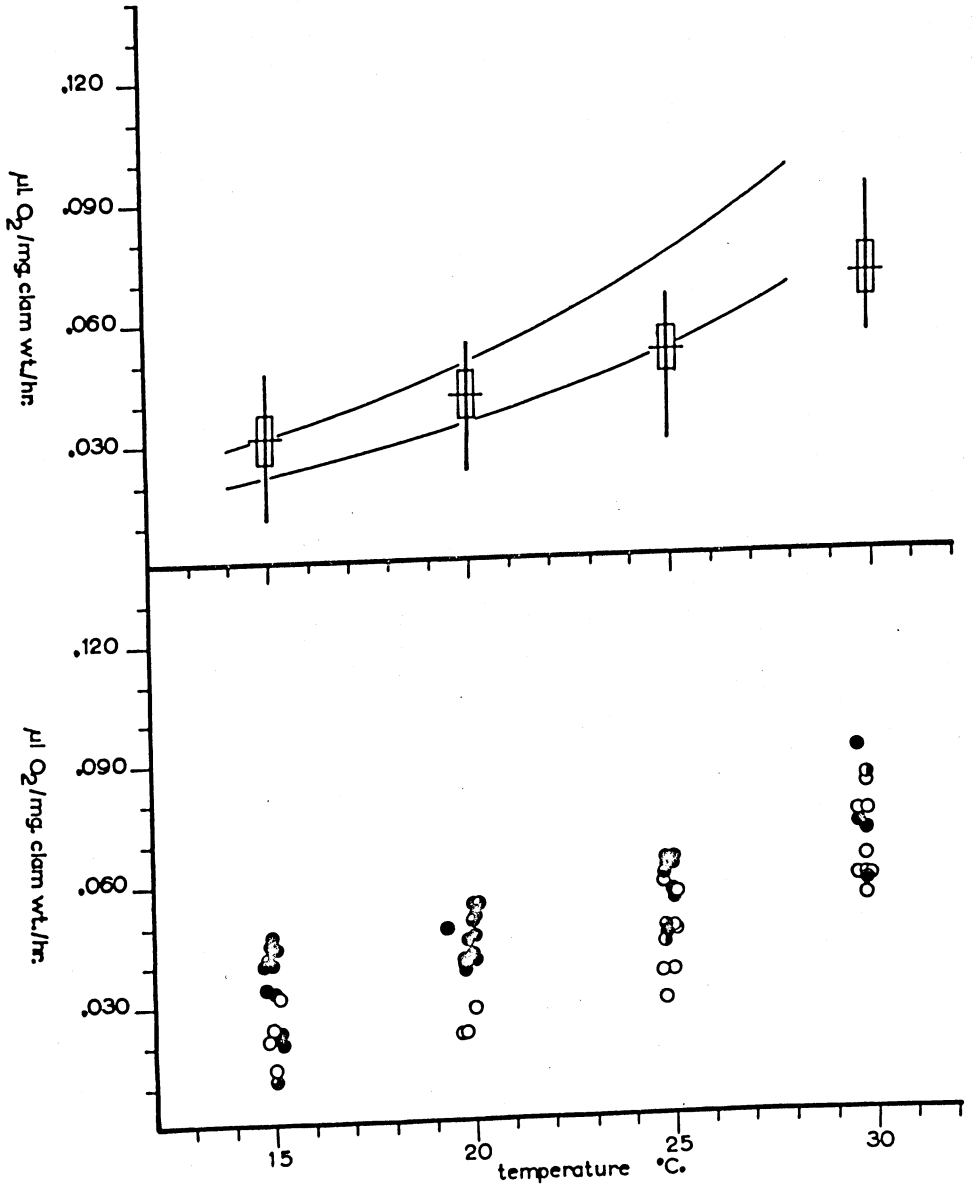

Fig. 14. Oxygen-consumption of active S. occidentale individuals in Respirometer A at various temperatures. SYMBOLS - VERTICAL LINE = RANGE, HORIZONTAL LINE = MEAN, RECTANGLE = ±2 STANDARD ERRORS, CURVED LINES = KROGH'S CURVE FITTED AT 15° AND 25° C., ● = MOVING AND SIPHONING, O = SIPHONING ONLY

Individual clams were placed in the animal chamber (0.8 ml. capacity) with approximately 0.10 ml. of distilled water. This water, which failed to cover the valves, was sufficient for siphon and foot activity, yet by its minimal quantity allowed rapid diffusion across the surface. Cruickshank (1954) found a similar method to function well using slices of tissue. While no chamber stirrer was employed, the water-bath stirrer vibrated the whole apparatus so that gas equilibration was probably enhanced.

Below is a summary of the number of experiments, the temperature range, the mean clam weight, and the range in clam weights.

Number	Mean Duration (hrs.)	Temperature °C	Mean Clam Wt. (mgs)
16	1.1	15 (14.70-15.30)	54.33 (40.0-67.5)
15	1.1	20 (19.80-20.27)	55.26 (40.0-68.4)
17	1.2	25 (24.80-25.20)	52.98 (41.4-66.8)

Blanks, utilizing the water in which the clam was active, were taken after each run in this series. Each blank value was then subtracted from its experimental value. Following is a table summarizing the blank values. Results appear in Tables 8-10 and in Fig. 15.

Number	Mean Duration (hrs.)	Temperature Range	Mean $\mu l\ O_2$ per hr.	Range
16	2.19	14.70-15.30	-.078	.000 to -.216 SE .0176
15	1.28	19.80-20.27	-.049	.000 to -.158 SE .0116
17	1.41	24.80-25.20	-.202	.000 to -.380 SE .0318

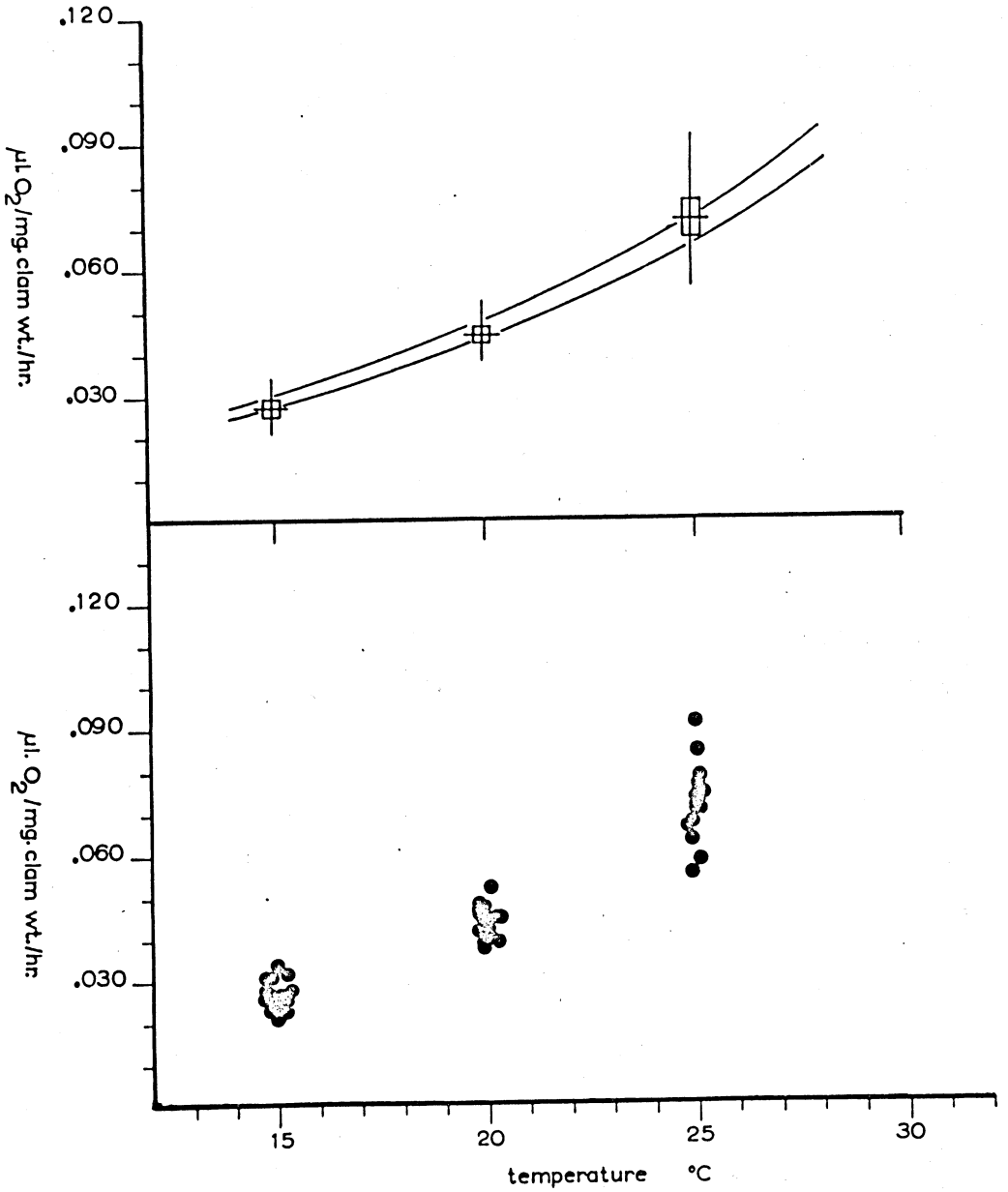

Fig. 15. Oxygen-consumption of active S. occidentale individuals in Respirometer B at various temperatures. SYMBOLS - VERTICAL LINE = RANGE, HORIZONTAL LINE = MEAN, RECTANGLE = ± 2 STANDARD ERRORS, CURVED LINES = KROGH'S CURVE FITTED AT 15° AND 25° C., ● = MOVING AND SIPHONING.

OXYGEN-UPTAKE OF INACTIVE CLAMS

Oxygen-uptake of inactive clams, i.e., animals with the siphons and foot withdrawn and the valves compressed, was measured with Respirometer B. Following cleaning, the individual was coated with enough water to thoroughly moisten the shell but with an amount insufficient for activity. Because of the small volumes involved, the runs were necessarily of long duration.

Some of the dimensions of the experiments are given below:

Number	Mean Duration (hrs.)	Temperature °C	Mean Clam Wt. (mgs)
17	4.34	15 (14.65-16.20)	57.61 (37.2-83.9)
22	4.16	20 (19.35-20.49)	51.75 (36.2-71.5)
11	6.86	25 (24.96-25.05)	54.26 (40.1-65.2)
21	4.07	30 (29.60-29.80)	56.63 (30.6-90.2)

Blank runs were interspersed among the experiments. Following is a summary of the blank runs, the average values being subtracted from each experimental value in the final calculations.

Number	Mean Duration (hrs.)	Temperature Range	Mean $\mu l\ O_2$ per hr.	Range
17	5.05	14.50-16.15	-.003	+.136 to -.157
15	4.38	19.20-20.49	-.010	+.090 to -.090
15	5.87	24.80-25.30	-.021	+.015 to -.088
15	4.23	29.60-29.95	-.062	+.060 to -.279

The results of this series of experiments are shown in Tables 11-14 and graphically shown in Fig. 9.

Oxygen-uptake of moist inactive clams treated with antiseptic

In order to evaluate the possible contributions of microorganisms on the surface of the shell to the inactive-clam values, the following modification was made. The oxygen consumption of four groups, composed of 3 clams each, was measured by the standard procedure described earlier. The same clams were then treated with an aqueous solution (1:1000) of (Zephiran) alkyldimethylbenzyl ammonium chloride for one minute. Subsequent to this treatment and a distilled water wash, the oxygen-uptake was again measured.

The average blank (-.003 ul per hr.) of the inactive-moist series was used. Following are the data.

	untreated			treated		
Temp. °C	µl O_2/ hr/ clam	µl O_2/ hr/mg	Mean Clam Weight	µl O_2/ hr/ clam	µl O_2/ hr/mg	% O_2 uptake treated / untreated
17.00	.222	.004	50.8	.190	.004	86
14.50	.161	.004	41.6	.116	.003	72
14.80	.248	.006	43.5	.204	.005	82
14.70	.220	.004	54.6	.164	.003	74
					mean	78.5

Oxygen-uptake of moist-surface and dry-surface inactive clams

The following experiment was conducted to measure the change of oxygen consumption when the same clams were measured in two states, namely, moist-surface inactive and dry-surface inactive. Each aggregate was composed of 3-30 equally sized clams. Average sizes of the clams in a group varied from 1.6 to 86 milligrams.

Oxygen-uptake of the moist-inactive clams was first determined by the method previously described. The only alteration was with regard to the smallest sizes, in which case, the molluscs were placed on sterile, almost saturated cellulose discs in order to minimize drying.

Following the above run, the surfaces of the same clams were allowed to dry until the shell changed from a translucent to an opaque appearance. Drying required 1-5 minutes, depending on the size of the organisms and the drying pressure of the room. Oxygen-uptake of the

same aggregate of clams was again measured but the molluscs were not in contact with moisture. Both conditions involved air close to saturation. All runs were at 25° C.

Subsequent to oxygen consumption determinations, the aggregates were weighed to the nearest 0.1 milligram and the result used to calculate the average clam weight. Volumes of each group were then measured three times and the mean used to calculate the average volume of a clam.

From the average volume value the relative surface area per clam was computed from the formula $S = XV^{2/3}$, where S is the surface area, V is the volume, and X is a constant for the species. The above formula gives actual surface area; however, the constant, X, was never determined, so the resulting values describe relative surface area only.

The data appear in Tables 15-18 and are graphed in Figs. 16 and 17.

Results

Active Clams

In Respirometer A, with a stirrer, the following results were realized.

Temp °C	No. of Experiments	Mean Total Weight	Mean µl O_2/ hr/clam	Mean µl O_2/ hr/mg	S.D. of Mean[1]	S.E. of Mean[1]
15	15	50.76	1.58	.0313	.01170	.003021
20	15	47.79	1.96	.0409	.01049	.002708
25	17	55.82	2.86	.0504	.01078	.002614
30	13	58.54	4.00	.0694	.01162	.003222

The overall mean weight for the 60 clams used was 53.14 mgs.

Ancillary to the data on oxygen-uptake, it was found that the water content of the above clams averaged 74.5 percent of the total weights of the above molluscs. Below is a summary from which these data were realized.

No. of Clams	Mean Total Wt. (mgs)	Mean Dry Wt. 60° C	Mean Total Wt. - Dry Wt.	Mean Percent Water
15	50.76	13.30	37.45	73.76
15	47.79	12.30	35.49	74.09
17	55.82	13.60	42.22	75.62
13	58.54	14.90	43.64	74.62
Overall means of 60 individuals				
	53.14	13.48	39.66	74.51

The dry weight of the molluscs of this series would therefore be 25.5 percent of the total weight. Water content varied from 71.2 to 78.0 percent in individual clams.

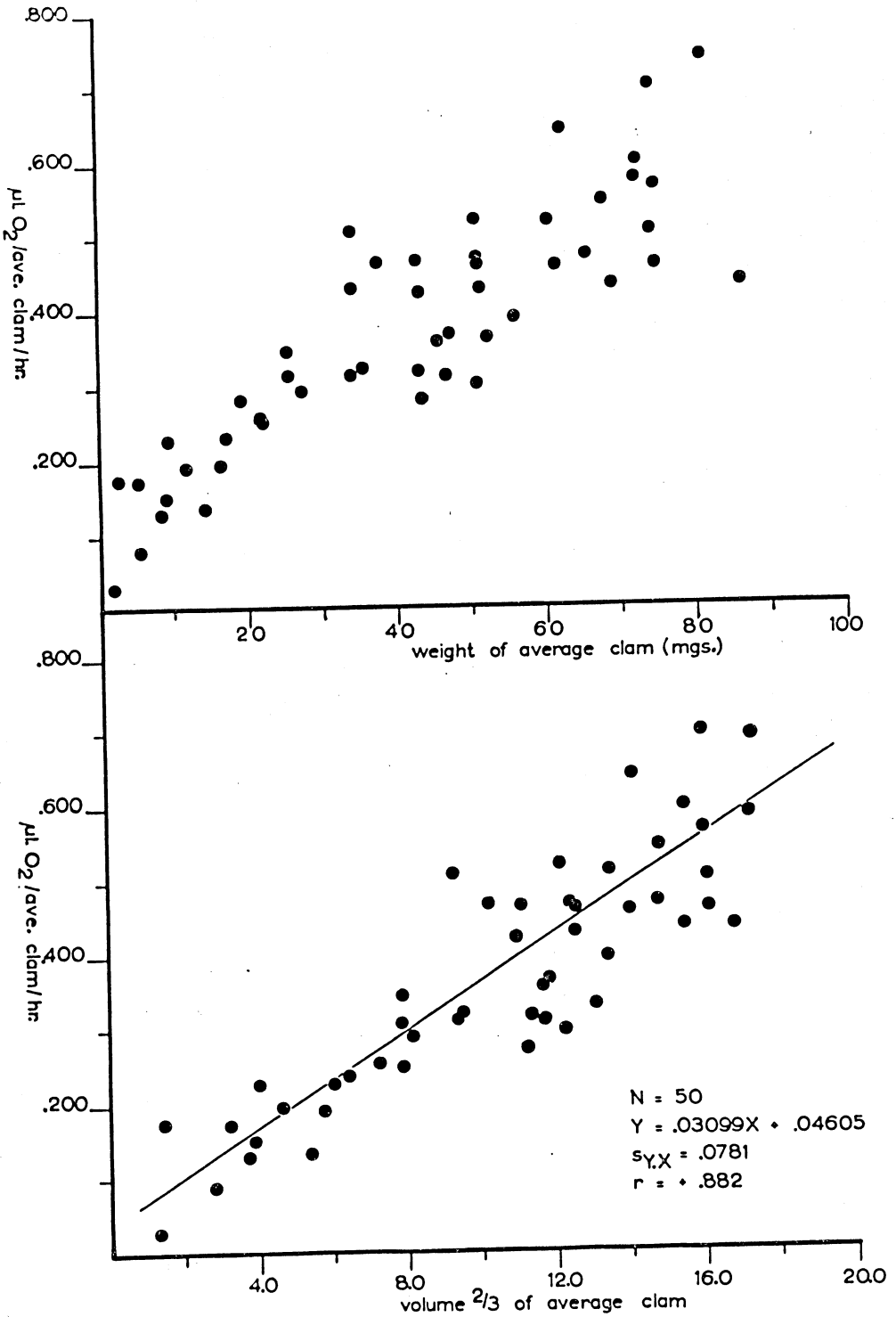

Fig. 16. Oxygen consumption of moist surface, inactive groups of S. occidentale in relation to clam weight and relative surface area.

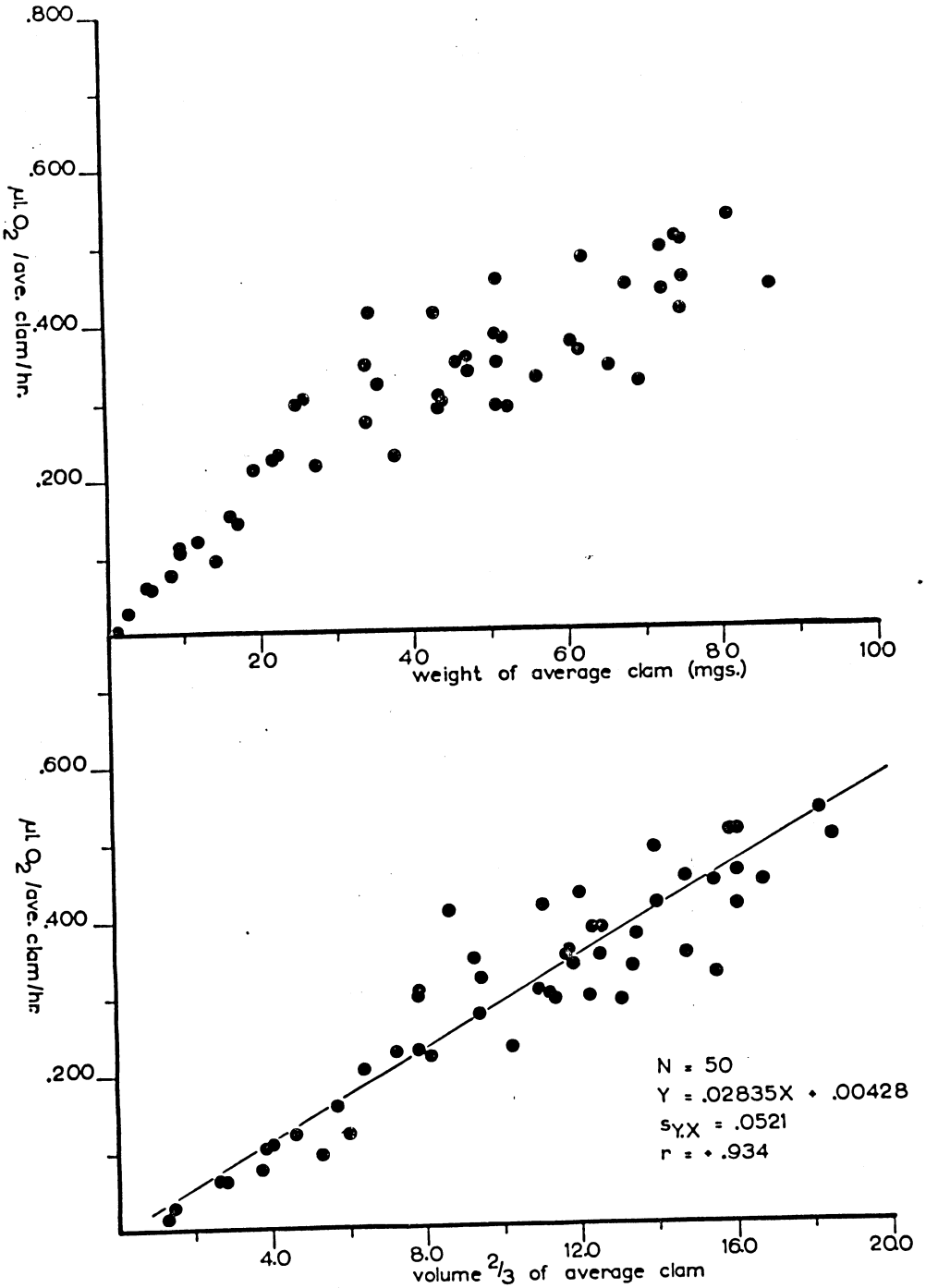

Fig. 17. Oxygen consumption of dry surface, inactive groups of S. occidentale in relation to clam weight and relative surface area.

Below is summarized the results from Respirometer B which did not employ a stirrer.

Temp. °C	No. of Experiments	Mean Total Weight	Mean µl O_2/ hr/clam	Mean µl O_2/ mg/hr	
15	5	43.7	1.154	.026	
	6	54.2	1.572	.029	
	5	64.2	1.695	.026	
Overall Means		54.33	1.479	.027	S.D. = .0035 S.E. = .0009
20	5	45.3	2.016	.044	
	5	54.9	2.345	.042	
	5	65.5	2.956	.045	
Overall Means		55.26	2.439	.044	S.D. = .0038 S.E. = .0010
25	7	43.5	3.101	.071	
	5	54.7	3.899	.071	
	5	64.6	4.620	.072	
Overall Means		52.98	3.783	.071	S.D. = .0083 S.E. = .0021

Inactive Clams

A synopsis of the oxygen-uptake of individual inactive moist clams is given below and the complete tabulation presented in Tables 11-14. The same information is shown graphically in Fig. 9.

Temp. °C	No. of Experiments	Mean Total Weight	Mean µl O_2/clam/hr	Mean[1] µl O_2/mg/hr	S.D. of Mean[1]	S.E. of Mean[1]
15	17	57.61	.232	.0040	.0011	.00026
20	22	51.75	.248	.0048	.0013	.00027
25	11	54.26	.400	.0073	.0019	.00056
30	21	56.63	.588	.0103	.0025	.00054

Subordinate to the measurements of oxygen-uptake, it was found that the 131 sphaeriids totally had a mean water content of 73.8 percent. In the next section on dessication, the value 26 percent for dry weight will be used as a base. Following are the data:

No. of Clams	Mean Total Wt. (mgs)	Mean Dry Wt. 60° C	Mean Total Wt. - Dry Wt.	Mean % Water
17	57.61	15.48	42.13	72.85
22	51.75	13.71	38.03	73.35
11	54.26	13.72	40.54	74.66
21	56.63	15.47	41.16	72.70
71				
Overall Mean	54.99	14.66	40.33	73.24

Combined with previous data on drying gives:

131	54.14	14.12	40.02	73.82

Zephiran chloride treated (1 min. in 1:1000 solution)

(Repeated from page 60.)

	untreated			treated		
Temp. °C	µl O_2/ hr/ave. clam	µl O_2/ mg/hr	Ave. Clam Wt.	µl O_2/ hr/ave. clam	µl O_2/ mg/hr	% O_2/clam treated to untreated
17.00	.222	.0044	50.8	.190	.0037	86
14.50	.161	.0039	41.6	.116	.0028	72
14.80	.248	.0057	43.5	.204	.0047	82
14.70	.220	.0040	54.6	.164	.0030	74
					Mean	78.5

Oxygen-uptake of moist and surface-dry clams

The itemized presentation of the data is given in Tables 15-18 and produced graphically in Figs. 16 and 17.

Following is a summary, arranged according to size classes, of that data. Measurements from Group #3 were not included in these calculations because of the likelihood of foot activity by some of the clams.

No. of Clams	Size Class (mgs)	Mean[1] O_2/mg/hr.	S.D. of Mean[1]	S.E. of Mean[1]	Mean[2] µl O_2/vol. 2/3 hr.	S.D. of Mean[2]	S.E. of Mean[2]
			Moist-Surface				
11	1-20	.0169	.0064	.00192	.0385	.0129	.00389
10	21-40	.0118	.0019	.00060	.0400	.0076	.00240
14	41-60	.0080	.0016	.00043	.0320	.0064	.00171
14	61-86	.0076	.0015	.00040	.0350	.0063	.00168
			Dry-Surface				
12	1-20	.0107	.0030	.00087	.0231	.0059	.00169
10	21-40	.0097	.0020	.00063	.0332	.0071	.00225
14	41-60	.0071	.0011	.00029	.0286	.0046	.00123
14	61-86	.0064	.0008	.00021	.0282	.0035	.00093

When the fifty individual percent reductions in oxygen-uptake from the moist-surface condition to the dry-surface condition were averaged, the mean value of 79.6 percent was found for the reduction per clam, 80.2 for the unit weight, and 79.4 percent for relative surface area.

As a check on the individual volume determinations made earlier, volumes of aggregates of clams that were used in the respiration studies were employed. In Fig. 11 the average volume for a clam is plotted against the average weight, and the relationship expressed by the regression line (least-squares method) $Y = .8543X + .2765$. The correlation coefficient

was found to be .995 and the standard error of the estimate, 1.379. While not identical to the regression line seen in Fig. 10, the similarity reinforces the accuracy of the method.

Discussion

A comparison of the measurements of oxygen-uptake by the active sphaeriids in Respirometer A and B reveals considerable variation, particularly at the extreme temperatures.

Fitted at 15° and 25° C., Krogh's curve (1914) was superimposed on both sets of data (Figs. 9, 14 and 15.) Although no statistics were applied, the curve correlates well with the results from Respirometer B. The values from Respirometer A are not significantly different from those of B at 15° but are much below the expectations of Krogh's curve at the higher temperatures. Berg et. al. (1962) found oxygen consumption of the circumboreal species, Pisidium casertanum, to follow Krogh's curve at a temperature range of 7-13° C.

These discrepancies were predicted from observations on the clams in the two respirometers: clams in Respirometer A were inhibited or hindered by the stirrer blade and current whereas the molluscs in Respirometer B were extremely active. Certainly the conditions in the second instrument more closely approached the lentic habitat of this species.

Because of the smaller standard errors, better uniformity of clam sizes, and the comparability of activity, greater confidence is placed in the results of Respirometer B.

In Respirometer B the three size-classes of active sphaeriids, namely the 40-50, 51-60, and 61-70 milligram sizes, showed no obvious differences in their mean oxygen-uptake per milligram of total weight at the three temperatures tested. The mean values of all the size classes were .027, .044, and .071 microliters oxygen per milligram of total weight at temperatures 15, 20, and 25° C. respectively.

Berg, et. al. (1962) found Pisidium casertanum to consume slightly less than 0.2 µl O_2/hr. per individual of 2 milligrams wet weight at 13° C., the highest temperature for the particular experiment. These workers also found that starvation for a period as long as sixty hours seemed to have only a slight effect on oxygen consumption. At 15° C. values dropped from approximately 0.55 µl/hr/individual of 3 milligram wet weight to about 0.50 µl during a period of 45 hours. In the same paper, Berg et. al. found that under controlled gas mixtures the oxygen-uptake decreased steadily with a diminishing oxygen content until about the 3-6 percent level, at which point oxygen-uptake decreased more rapidly. In a more exacting replicate of the effect of oxygen tensions, Berg and Jonasson

(1965) reported an average individual of 2.6 milligrams wet weight consumed about 0.04 µl O_2/hr in water, at 16° C., containing 2.2% oxygen. At 8° C. an average individual of 1.9 mg. wet weight consumed 0.06 µl O_2/hr in water containing 1.8% oxygen. Strangely their results show a decrease of almost half when the temperature was doubled. These workers attributed the findings to the difference in clams at the sampling times, the high value being during the reproductive phase and the low value, high-temperature, results reflecting animals in a non-productive period. However, their studies were conducted with groups of clams whose individual activities were apparently not controlled nor measured.

Alimov (1965) found the fingernail clam Sphaerium corneum, taken from streams of different salinities, not to have appreciably different oxygen consumptions. However, the oxygen-uptake did vary with size of the organism and season. The greatest use of oxygen occurred in clams of 4-8 mm. in length (14-152 mgs), while the 9-13 mm. molluscs (616 mgs) maintained an almost constant consumption of .02 mgs O_2/hr/gram total weight. Clams of 4 mm. length (14 mgs) showed a distinct seasonal variation in oxygen-uptake, which varied from 0.26 mgs O_2/hr/gm total weight at 20° C. in the summer to 0.11-0.13 mgs in the fall. These data were derived from changes in oxygen content of bottles containing from 1-3 animals, replicated nine times.

Some of the data of Alimov for comparably sized specimens agree with the results of this report. However, the values of Alimov are generally somewhat higher. Little agreement was found between the values reported by Berg (1962) and the current findings; however, size and technique were probably the most influential factors.

Apparently many species of sphaeriids maintain themselves anerobically when the valves are closed. Jatzenko (1928) showed that Sphaerium corneum could endure one and one-half months without oxygen. Juday (1908) discovered Pisidium idahoense living in the profundal zone of a Wisconsin lake for a period of three to four months when no oxygen could be detected. Many distributional reports for the clams suggest anerobic conditions. In the present study no tests were made on this type of respiration. Instead, inactive clams were studied for oxygen-uptake.

Fig. 9 depicts the oxygen-uptake of moist-surface, inactive clams of similar size at temperatures of 15, 20, 25, and 30° C. The values per clam and per milligram clam weight approach one-ninth to one-tenth of the volumes consumed by active clams in Respirometer B. That the consumptions in the two states are roughly proportional is evidenced by the fit of Krogh's curve to both sets of data. No statistics were applied to the goodness of fit.

Oxygen utilized by inactive clams could be related to (1) epizooics and epiphytes on the shell or (2) uptake by the clams. If microorganisms are responsible they would presumably be associated with the general surface of the valves. If the clam is removing oxygen in this inactive state, the site of exchange would have to be demonstrated.

In the comparison of oxygen consumption by moist-surface clams and the uptake by the same clams which had received a treatment of the bactericide Zephiran chloride, it was found that treated animals demonstrated a mean uptake of 78.5 percent of the untreated values. Results ranged from 72-86 percent.

The experiment involving uptake of aggregates of similar-sized clams, first measured in the moist-surface condition and subsequently in the dry-surface state, showed that in both cases oxygen consumption varies inversely but not geometrically with the average weight of the clam regardless of the condition. When the values were plotted against relative surface area, a straight-line relationship was suggested. Correlation was better (correlation coefficient .934) for the dry-surface values than the moist-surface (correlation coefficient .882). The standard error of the estimate of the dry-surface animals was somewhat smaller (.052) than that of the moist-surface clams (.078). The regression lines were not identical

(Moist: Y = .04605 + .03099X; Dry: Y = .00428 + .02835X). It is of particular interest that the mean uptake by all the aggregates of the dry-surface sphaeriids amounted to 79.6 percent of the moist-surface values per clam, 80.2 percent per unit weight, and 79.4 percent per relative surface area.

While the data do not clearly establish if the volumes consumed by the inactive animals were due to the molluscs or to surface microorganisms, the possibility of the clam, and more specifically, the pyramidal cells, being involved is valid. In Fig. 5 it was shown that as a clam grows the number of pyrimidal cells increases in a wave from the umbone toward the periphery. It is plausible therefore that a constant number of punctae is maintained relative to the whole surface area of the valve. As a consequence, assuming the pyramidal cells responsible for the oxygen-uptake, there would be a direct correlation between surface area and oxygen-use.

Some simple calculations lend support to the argument. Inspection of the clam shows that if an arbitrary-sized circular area were circumscribed around the umbone, the mid-valve surface would be found to contain approximately three of these units, and the marginal area, including the rim, five. If the mean numbers of punctae per area of the various size classes are multiplied by these factors, and the results added, the relative number of punctae per

valve can be estimated. By dividing this estimate by the number of fields (factors), the relative average punctae density can be approximated. As will be shown below, this value approaches a constant for valves of various sizes.

For the 10-19 mg. (D) clams, the mid-regional area was divided equally between the umbonal and marginal. Because only one area was sampled, the value of 7.01 from the smallest size was not factored. The results expressed are for the 60-79 mg. (A) group, 6.08; 40-59 mg. (B) group, 5.54; 20-39 mg. (C) group, 4.60; 10-19 mg. (D) group, 5.72; 1-3 mg. (Y) group, 7.01.

An alternative to the pyramidal cells as the involved components is the general mantle surface beneath the shell. Although the shell would seem to present a barrier to diffusion, some evidence exists to support its involvement. Mitchell (1912) found empty shells to change the oxygen content of water, presumably as a result of bacteria. However, the same author reported that pieces of porcelain had the same effect.

Jatzenko (1928) and Gartkiewicz (1926) studied heart beat in relation to temperature and active or inactive states of young Sphaerium. Gartkiewicz found that the systolic rate of active clams was 20-26 times that of the resting animals. Similarly Jatzenko

(1928) found the heart beat to vary from 2-48 times per minute, being much higher when the siphons and foot were extended than when closed. At 19° C the difference was usually a factor of 10 (4-40 beats per minute). Of interest is that in the present study the difference in oxygen-uptake by active and inactive clams at 20° C. approaches the same magnitude. Noteworthy is the fact that the umbonal concentration of punctae coincides with the position of the metabolically active organs.

If the oxygen-uptake values of the inactive clams are due to surface contaminants, it is obvious that the active clam values would have to be corrected in order to accurately reflect branchial respiration. On the other hand, if the pyrimidal cells (or general surface) are involved in oxygen transport, as herein proposed, the advantages to the clam are obvious. Oxygen could be absorbed when conditions of moisture prevented branchial respiration, and the animal could utilize, at least somewhat, the more efficient aerobic respiration. Whether this function could be maintained under severe or prolonged desiccation was not studied. However, even in water certain advantages can be visualized. The tremendous increase in metabolism, almost reflexive in action, that is associated with the opening of the valves is avoided. Such a function assigned to the pyrimidal cells would not obviate other physiologic

roles, such as sensory functions or shell maintenance elements in the clam.

Weight loss and longevity under controlled humidities

Drought is the major factor in aestivation. As observed earlier, S. occidentale often survives weeks or months in the organic substrate of temporary woodland ponds. The more exposed clams frequently show a bubble in the mantle cavity.

The following set of experiments was designed to determine the weight loss and longevity of the fingernail clams under controlled humidities.

Apparatus

Saturated salt solutions in enclosed containers were used for relative humidity control. Equilibrium at 20° C. produces the following theoretical relative humidities (Wexler and Hasegawa, 1954) and the calculated vapor pressure deficits:

Solution	% Relative Humidity	Vapor Pressure Deficit
LiCl	12.4	15.43
$MgCl_2$	33.6	11.75
NaCl	75.5	4.38
H_2O	100.0	0.00

Desiccation chambers for each of the above consisted of one-gallon, wide-mouth, glass jars. From

a nut soldered to the center of each lid, a threaded ¼-inch bar was vertically fitted. This bar served to hold the animal racks above the solution.

Clam holders were constructed from 3 3/4-inch diameter plexiglass discs through which were drilled forty-five holes of 5/8-inch diameter plus a center hole for suspension. Vinyl-covered fiberglass screening (1/16-inch mesh) was glued to the bottom surface of each disc and the excess trimmed, thereby producing well-ventilated depressions for individual clams. Three, one-inch long screws served as legs for each specimen plate.

Five such plates, suspended from the center rod and separated by the screw legs were used in each container, giving a possible maximum of 225 individual spaces per rack. Each tray was lettered and a code of marks employed for locating specific depressions.

Approximately two inches of water and salt in excess of saturation was added to each jar. After the rims were heavily greased, and the jars capped, they were placed in a room held at 20° C. (±2° C.).

Ten checks with an electronic hygrometer during the course of the experiment gave the following relative humidities:

Solution	Relative Humidity Range	Average	Calculated Vapor Pressure Deficit
LiCl	12-13	13	15.27
$MgCl_2$	30-36	35	11.49
NaCl	68-72	70	5.06
H_2O	90-96	93	1.23

The differences between the theoretical and the observed values are not greatly dissimilar from those recorded by Von Brand, McMahon, and Nolan (1957). Wexler and Hasegawa caution the worker on the slow attainment of equilibria because of the amount of surface area, absence of stirring, and the presence of hygroscopic materials, so that in general use these solutions will not achieve relative humidities closer than one percent of the theoretical values. The absence of stirring and the frequent removal of samples were believed to have caused much of the discrepancy.

About 1500 clams were collected on 3-4 August 1961 from the moist leaf mold of the study pond and were transported to the laboratory in this material. After innundation, the molluscs were supplied food and acclimatized at 20° C. for one week.

After their surfaces were air dried, the clams were weighed to the nearest milligram on a Roller-Smith balance ($\pm$ 1 mg.). Clams were then returned to flooded plastic depression trays until a supply for a

desiccator was complete, at which time they were again surface-dried and placed in the desiccator plates.

At almost daily intervals initially, later at more extended periods, a random sample of approximately ten clams was removed from each desiccator. These clams were weighed, and the percent weight loss calculated.

Viability was determined by squashing the animal and examining its branchial epithelium for movement of the cilia, which Gartkiewicz (1926) claimed were immobile in the resting clam. Often this observation was unnecessary because the tissues were decayed. Viability, as characterized here, does not infer that the animal was capable of rehydrating and sustaining itself upon return to the aquatic environment.

In those molluscs showing ciliary movement the soft tissues were teased for the presence of marsupial young. Their numbers were not determined.

Results

Because the viability of the clams could not be determined by observation, a sample (usually ten) of the organisms was periodically removed, weighed, squashed, and viewed for ciliary movement. Longevity studies therefore were based on the sample, LD50 being the duration in hours beyond which half or more of the clams in subsequent samples showed no ciliary activity.

While some loss of weight would result from oxidation of metabolites, the reductions in weight considered here will be termed water loss. No attempt was made to correct mortality for causes other than drying.

In the 93 percent R.H. chamber, no LD50 was established. The results are presented in Table 19 and diagrammed in Fig. 18. The experiment was terminated at 432 hours, at which time the mean weight of the survivors was 95.4 percent of their original weight. Condensation and mold were present on some individuals. Of the 142 live clams totally sampled, 130 contained young.

In the 70 percent R.H. chamber, no mold or water was present and the experiment was maintained for 765 hours. Table 20 contains the data, which is graphed in Fig. 18. The LD50 exists between 512 and 765 hours. The average percent original weight of the live animals at 512 hours was 68.3 percent. In the population of 113 live animals, young were found in 107 of them.

At 35 percent R.H. the LD50 occurred at 127 hours. The survivors had a mean weight of 80.8 percent of the original. In Fig. 19 and in Table 21 it can be seen that a few organisms maintained high weights until almost the termination of the experiment at 407 hours. Forty-six of the forty-nine live animals included in the samples possessed young. Table 22 and Fig. 19 present the results of the thirteen percent R.H.

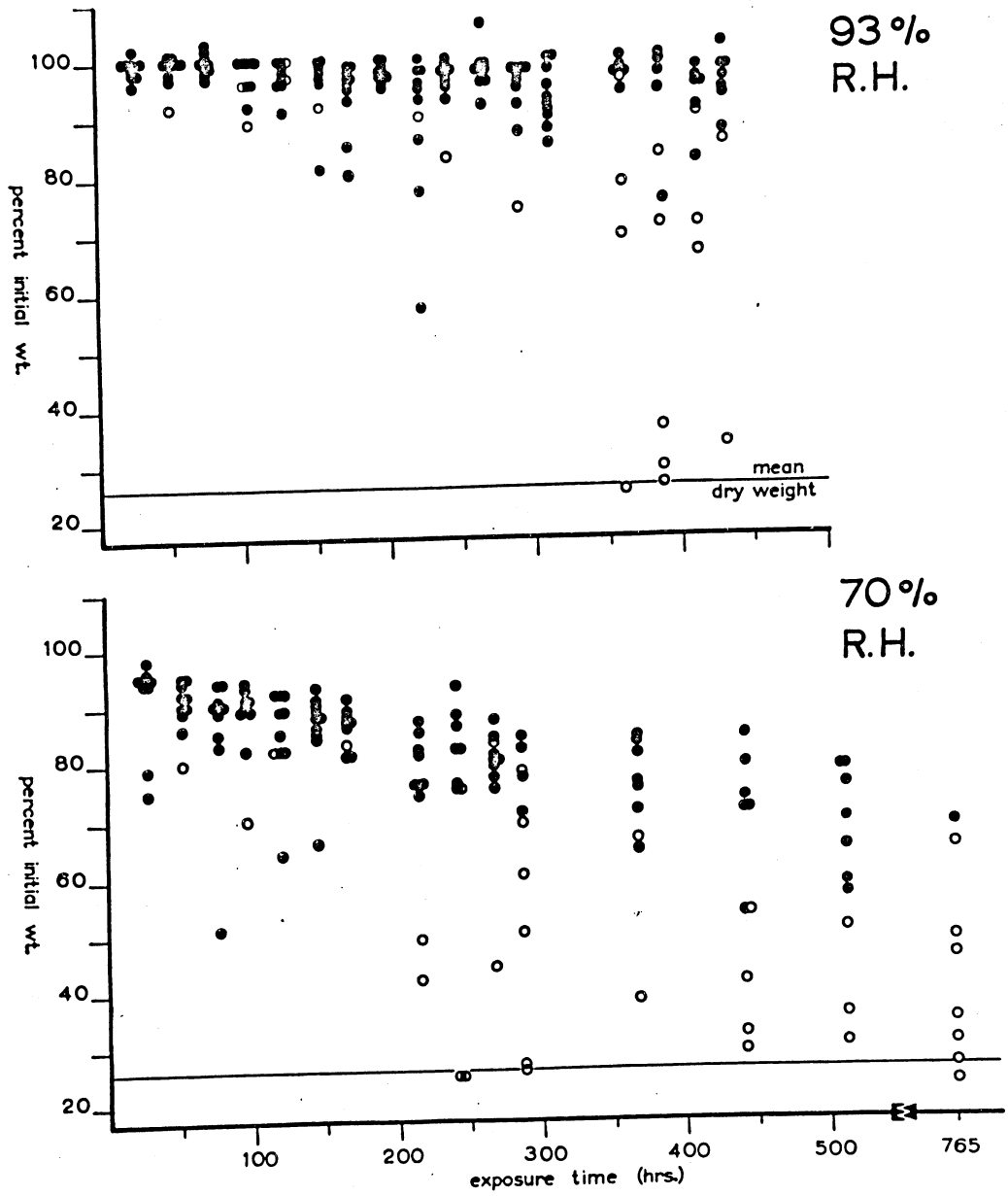

Fig. 18. Longevity and weight loss of S. occidentale at 93 % and 70 % relative humidities, 20° C. ● = LIVE CLAM (CILIARY ACTIVITY), O = DEAD CLAM (NO CILIARY ACTIVITY)

experiment. LD50 occurred at 142 hours, at which time the live sample weighed an average of 71.2 percent of the original weight. A considerable number of the clams, however, maintained themselves at the 60-80 percent range until the termination of the experiment at 381 hours. Sixty-one of the sixty-five live clams contained young.

The greatest reduction of any individual was to 46 percent of the original weight, a loss that represented a calculated 73 percent of the water content of the animal. Sphaerium occidentale was shown previously to average about 74 percent water.

Out of the total of 369 live clams squashed, only three contained sporocysts or cercaria believed to be members of the trematode family Gorgoderidae.

Discussion

Sphaerium occidentale appears to possess no special ability to resist desiccation. While the LD50 values are not in complete agreement with the expectation based on the vapor pressure deficits, the general trend is present. For instance, with the assumption that the data for the 70 percent R.H. chamber are valid, the vapor pressure deficits would predict the LD50 to occur in half the time for the 35 percent R.H. chamber and in about one-third the time in the 13 R.H. chamber. Both are considerably lower. Because of the many

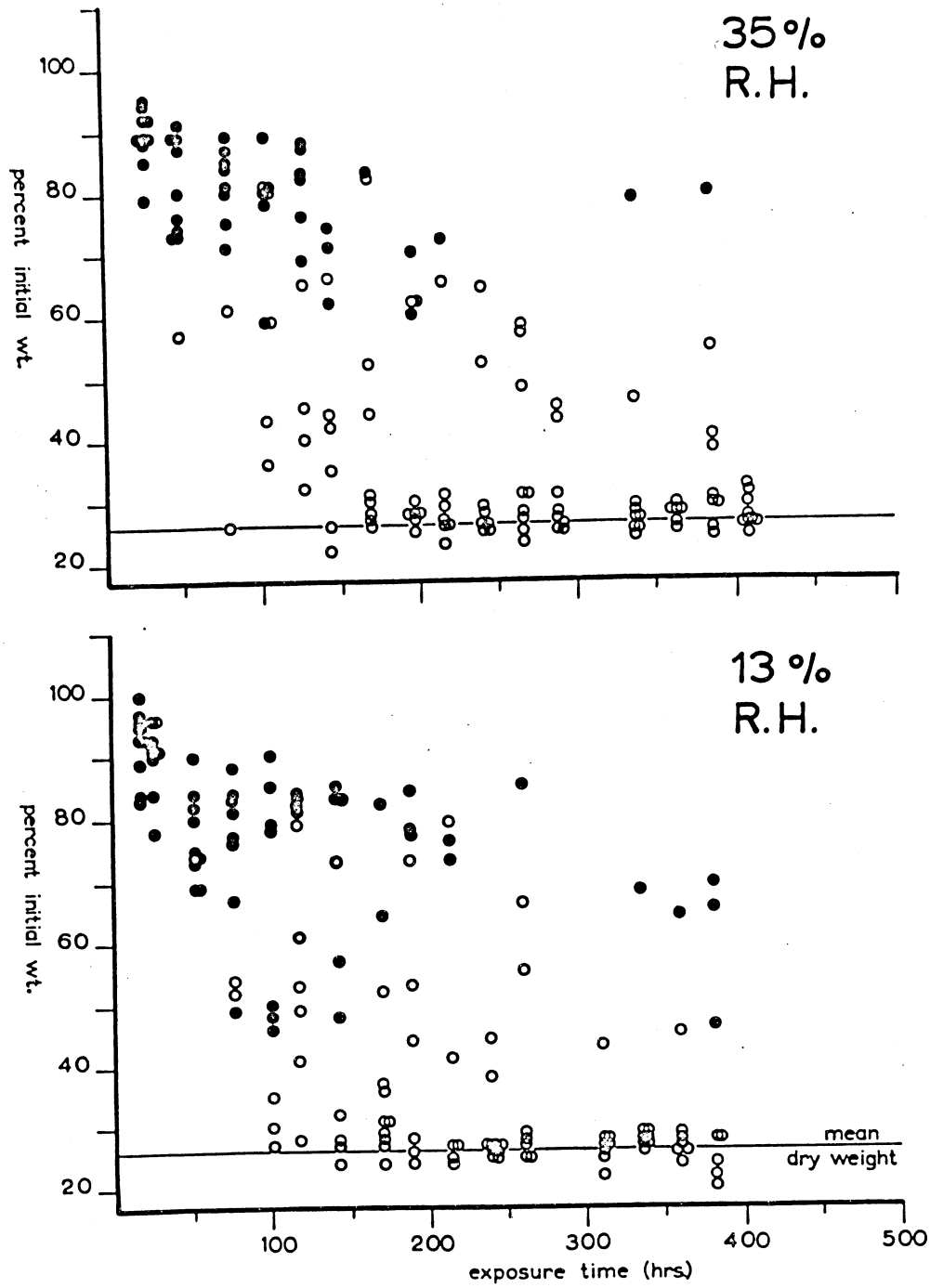

Fig. 19. Longevity and weight loss of S. occidentale at 35% and 13% relative humidities, 20° C. ● = LIVE CLAM (CILIARY ACTIVITY), O = DEAD CLAM (NO CILIARY ACTIVITY)

variables including size and condition of the clams, local inequilibria in the chambers, and the strong odor of methacrylate emanating from the plastic discs, the results are not surprising.

It is interesting that at the lower humidities most of the clams lost water rapidly and died, whereas about one-third of the animals were able to maintain themselves at a high degree of hydration. While not studied, it was observed that some clams secreted considerable mucous in the holding tray, prior to their being blotted and transferred to the chambers.

The data seem to indicate that most clams die when the 60 percent level of original weight is approached. If this 40 percent loss represents only water, a 55 percent dehydration approximates the lethal point for the average clam.

This set of experiments emphasizes the importance of the microclimate, aestivating sites, and local weather in maintaining the population over a summer.

SUMMARY

In the period between 1960-1965, a study was conducted on certain aspects of the ecology, oxygen consumption, and desiccation of the fingernail clam, Sphaerium occidentale Prime. This species is characteristic of temporary woodland ponds.

In 1960 field studies on a northern Minnesota pool revealed that the population of clams did not concentrate in the residual open water as the pool dried; instead the migration was chiefly a vertical one into the leaf mold and humus. Superficially located clams sometimes showed a bubble in the mantle cavity. Microclimate temperatures were moderated by the insulating qualities of the duff. The density of the aestivating populations larger than 2 mm. in length was found to be about 1300-1400 per square meter.

Laboratory studies on the morphology of the sphaeriids revealed isometric relative growth for the measurements of length, height, shell weight, volume, and dry weight. Width was more variable. The umbone was found to be the thinnest part of the shell regardless of the size of the clam; however, all areas increased in thickness with growth. Punctae density and distribution varied inversely to the shell thickness in any size, but the densities increased with growth of the shell. The rim was devoid of punctae.

With laboratory-conditioned animals the mean oxygen-uptake of 40-60 milligrams, active clams was found to be .027 µl/mg/hr. at 15° C., .044 at 20° C., and .071 at 25° C. Consumption varied considerably with the degree of activity. Inactive, moist-surface clams of the same size group utilized .004 µl O_2/mg weight/hr. at 15° C., .005 at 20° C., .007 at 25° C., and .010 at 30° C. Values for both the active and inactive, moist-surface clams seemed to fit Krogh's curve. Disinfecting the clam surfaces with Zephiran chloride produced about a 20 percent reduction in oxygen consumption as did drying the surface of the clams.

Oxygen-uptake of aggregates of similar sized individuals (1-80 mgs) was correlated with relative area of the shell surface. Notwithstanding the possibilities of utilization by surface microorganisms or direct entry through the shell, uptake is proposed through the pyramidal cells (punctae), the function of which has remained speculative.

Desiccation of fingernail clams in four relative humidities, 13, 35, 70, and 93 percent, was measured by periodic removal of samples. Viability was determined by ciliary activity of squashed clams. The LD50 longevity of the population at 13 percent R.H. was 142 hours, at 35 percent R.H., 127 hours, at 70 percent R.H., between 512 and 765 hours. Mortality

was high when the weight approached 60 percent of the original. The mean water content of this species is 74 percent of the weight. Because Sphaerium occidentale does not seem particularly resistant to water loss, its survival during aestivation is probably dependent upon the microclimate.

APPENDIX

TABLE 1

SIZE CLASSES OF SPHAERIUM OCCIDENTALE AS FOUND IN THE DRY POND OF 13 AUGUST 1960. ORDER OF THE STATIONS IS FROM THE PERIPHERY TO DEEPEST PART OF POND

	Length in millimeters						
Station	2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	Total
26	5	6	0	0	1	0	12
21	3	5	1	2	2	0	13
17	11	12	5	3	4	0	35
1	4	5	1	0	0	0	10
2	0	0	0	1	1	0	2
3	7	5	2	1	3	0	18
4	5	8	1	0	1	0	15
5	0	2	1	5	2	0	10
6	8	4	2	4	7	0	25
22	3	3	4	0	0	0	10
33	3	1	2	3	3	0	12
35	8	4	4	4	0	0	20
28	6	4	0	2	2	0	14
29	4	2	0	0	0	0	6
36 1 P	7	0	4	3	2	1	17
19	6	4	1	0	0	0	11
*15	0	4	0	1	0	0	5
14	1	0	0	0	0	0	1
23	3	4	0	1	0	0	8
25	2	3	1	0	3	0	9
27	6	5	4	4	2	0	21

TABLE 1 - Continued

Station	Length in millimeters 2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	Total
32	9	6	1	2	0	0	18
37	1	2	5	0	2	0	10
20	2	1	1	0	0	0	4
18	3	0	1	1	0	0	5
16	3	6	1	2	0	0	12
12 1 P	2	9	3	2	1	1	18
30 2 P	2	1	1	4	3	0	11
* 7 1 P	6	2	3	2	0	0	13
8 1 P	5	7	7	7	5	1	32
24	9	1	0	0	0	0	10
39	3	0	0	0	2	0	5
31	8	4	4	3	1	1	21
9	4	3	2	1	0	2	12
38	4	1	3	2	1	0	11
40 1 P	3	3	3	1	0	0	10
13	1	0	1	1	0	0	3
10	0	2	1	1	0	0	4
11	0	0	0	0	0	0	0
34	1	1	0	0	0	0	2
	158	130	70	63	48	6	475
							+ 2
							477

P = Pisidium sp. found

* +1 clam less than 2 mm. in length

TABLE 2

DIMENSIONS OF THE VALVES OF VARIOUS SIZE CLAMS IN RELATION TO WEIGHT

Data No.	Clam Wt. (mg)	Shell Wt. (mg)	Meta-bolic Wt. (mg)	Vol. (ave. of 3 trials)	Length (mm)	Height (mm)	Width (mm)
A- 1	76.6	16.2	60.4	66	6.7	5.5	4.1
A- 2	66.5	15.0	51.5	57	6.4	5.2	3.9
A- 3	76.7	16.0	60.7	--	6.7	5.5	4.1
A- 4	64.3	14.2	50.1	56	6.4	5.2	3.6
A- 5	75.5	15.8	59.7	66	6.6	5.3	4.1
A- 6	77.0	16.1	60.9	--	6.9	5.6	4.1
A- 7	70.5	15.2	55.3	64	6.7	5.3	3.8
A- 8	67.7	14.6	53.1	60	6.3	5.2	3.8
A- 9	71.7	16.0	55.7	62	6.4	5.2	3.9
A-10	71.8	14.2	57.6	60	6.4	5.3	3.8
Mean	71.83	15.33	56.50	61.4	6.57	5.32	3.91
B- 1	47.0	10.5	36.5	42	5.7	4.8	3.2
B- 2	53.3	11.5	41.8	47	5.9	4.6	3.6
B- 3	44.2	8.9	35.3	41	5.7	4.8	3.2
B- 4	50.4	11.9	38.5	45	5.9	4.6	3.4
B- 5	43.9	9.3	34.6	39	5.6	4.8	3.4
B- 6	51.0	11.5	39.5	44	5.9	4.9	3.4
B- 7	55.3	12.2	43.1	49	6.2	4.9	3.5
B- 8	55.2	11.9	43.3	50	6.0	4.9	3.6
B- 9	39.8	9.1	30.7	35	5.5	4.3	4.3
B-10	41.7	9.5	32.2	37	5.6	4.3	3.2
Mean	48.18	10.63	37.56	42.9	5.80	4.69	3.49

TABLE 2 - Continued

Data No.	Clam Wt. (mg)	Shell Wt. (mg)	Meta-bolic Wt. (mg)	Vol. (ave. of 3 trials)	Length (mm)	Height (mm)	Width (mm)
C- 1	28.4	6.3	22.1	24	4.3	4.1	2.8
C- 2	33.2	7.0	26.2	30	5.0	4.2	3.1
C- 3	27.0	5.8	21.2	24	4.8	3.9	2.8
C- 4	31.2	7.1	24.1	28	5.3	4.2	3.1
C- 5	34.4	8.1	26.3	32	5.5	4.5	2.9
C- 6	32.5	7.1	25.4	29	5.3	4.3	2.9
C- 7	34.4	8.2	26.2	31	5.5	4.3	2.9
C- 8	34.1	7.6	26.5	30	5.2	4.1	3.1
C- 9	26.6	6.0	20.6	23	4.1	3.9	2.8
C-10	37.6	8.0	29.6	33	5.5	4.5	3.2
Mean	31.94	7.12	24.82	28.4	5.04	4.20	2.67
D- 1	12.4	3.2	9.2	10	3.8	3.1	2.1
D- 2	13.4	3.1	10.3	11	4.1	3.2	2.1
D- 3	15.7	3.5	12.2	15	4.2	3.4	2.2
D- 4	12.4	3.0	9.4	11	3.8	3.1	2.2
D- 5	11.0	2.5	8.5	11	3.8	2.9	2.1
D- 6	16.8	3.8	13.0	15	4.2	3.5	2.4
D- 7	11.6	2.6	9.0	10	3.8	2.9	2.0
D- 8	12.8	2.9	9.9	12	3.8	2.9	2.1
D- 9	13.2	3.1	10.1	12	3.8	3.1	2.1
D-10	17.8	4.2	13.6	16	4.3	3.5	2.2
Mean	13.71	3.19	10.52	12.3	3.95	3.16	2.16

TABLE 2 - Continued

Data No.	Clam Wt. (mg)	Shell Wt. (mg)	Meta-bolic Wt. (mg)	Vol. (ave. of 3 trials)	Length (mm)	Height (mm)	Width (mm)
Y- 1	2.3	0.5	1.8	--	2.4	1.8	--
Y- 2	0.9	---	---	--	1.8	1.4	--
Y- 3	0.9	0.2	0.7	--	1.3	1.4	--
Y- 4	1.4	0.3	1.1	--	2.0	1.5	--
Y- 5	1.3	0.3	1.0	--	2.0	1.4	--
Y- 6	2.1	0.6	1.5	--	2.2	1.7	--
Y- 7	1.6	0.4	1.2	--	2.2	1.5	--
Y- 8	1.8	---	---	--	2.2	1.7	--
Y- 9	1.6	---	---	--	2.1	1.5	--
Y-10	2.1	0.3	1.8	--	2.1	1.5	--
Mean	1.60	0.37	1.30		2.03	1.55	

TABLE 3

SHELL THICKNESS AND DISTRIBUTION OF PUNCTAE IN VARIOUS REGIONS OF DIFFERENT SIZE CLASSES OF CLAMS

	Ave. Punctae per field of .09 mm^2 (10-field mean)			Shell Thickness (mm)		
Data No.	Umbo	Mid	Margin	Umbo	Mid	Margin
A- 1	16.8 (15-20)	9.0 (8-10)	3.1 (1-5)	.05	.07	.11
A- 2	17.9 (15-22)	8.8 (7-11)	1.8 (0-3)	.05	.07	.10
A- 3	16.4 (14-18)	8.8 (6-10)	3.6 (1-5)	.05	.07	.12
A- 4	16.6 (12-21	5.8 (4- 7)	2.1 (0-4)	.04	.08	.10
A- 5	21.4 (19-24)	6.6 (5- 8)	2.6 (1-6)	.04	.07	.11
A- 6	16.2 (14-18)	9.9 (8-12)	2.7 (1-5)	.05	.07	.16
A- 7	18.2 (16-20)	10.2 (8-12)	2.1 (0-4)	.05	.06	.14
A- 8	12.0 (10-15)	9.0 (8-11)	3.2 (2-4)	.06	.08	.13
A- 9	19.1 (17-21)	6.6 (5- 8)	0.8 (0-2)	.05	.06	.11
A-10	18.9 (17-21)	8.4 (7-11)	2.9 (0-6)	.06	.08	.15
Mean	17.35	8.31	2.49	.050	.071	.123

TABLE 3 - Continued

Data No.	Ave. Punctae per field of .09 mm² (10-field mean)			Shell Thickness (mm)		
	Umbo	Mid	Margin	Umbo	Mid	Margin
B- 1	14.8 (14-17)	7.9 (7-10)	1.3 (0-3)	.04	.06	.10
B- 2	17.8 (16-21)	10.1 (7-13)	3.2 (2-5)	.05	.07	.09
B- 3	17.6 (14-22)	7.4 (6-10)	2.5 (1-3)	.04	.06	.08
B- 4	15.3 (12-20)	5.8 (4- 8)	2.7 (1-5)	.05	.05	.09
B- 5	20.6 (19-23)	4.6 (3- 7)	3.1 (2-5)	.04	.06	.11
B- 6	15.9 (14-19)	7.7 (5-11)	1.2 (0-2)	.04	.07	.10
B- 7	19.2 (14-22)	4.8 (3- 8)	2.7 (0-4)	.05	.06	.08
B- 8	18.3 (16-21)	7.9 (6- 9)	3.3 (1-5)	.03	.06	.11
B- 9	19.0 (16-21)	6.9 (4- 9)	2.0 (1-4)	.05	.06	.10
B-10	19.1 (17-21)	4.7 (3- 7)	1.6 (0-4)	.04	.06	.08
Mean	17.76	6.78	2.36	.043	.061	.094

TABLE 3 - Continued

Data No.	Ave. Punctae per field of .09 mm² (10-field mean)			Shell Thickness (mm)		
	Umbo	Mid	Margin	Umbo	Mid	Margin
C- 1	17.0 (14-21)	3.8 (3- 4)	2.4 (1-4)	.04	.06	.09
C- 2	17.0 (15-20)	6.7 (5- 8)	2.5 (1-4)	.04	.05	.10
C- 3	15.9 (14-19)	5.6 (4- 7)	1.2 (0-3)	.04	.05	.08
C- 4	15.9 (14-18)	4.7 (3- 7)	2.2 (1-5)	.05	.06	.09
C- 5	18.7 (15-24)	5.1 (4- 6)	1.6 (0-3)	.04	.05	.10
C- 6	16.9 (13-19)	8.2 (6-10)	2.0 (0-4)	.04	.04	.09
C- 7	12.7 (10-16)	5.8 (3- 9)	1.8 (1-2)	.04	.06	.09
C- 8	17.7 (15-20)	4.1 (2- 6)	1.4 (1-2)	.04	.05	.10
C- 9	17.2 (15-20)	3.8 (3- 5)	1.7 (0-4)	.05	.05	.08
C-10	19.9 (16-23)	3.8 (2- 5)	1.3 (0-2)	.04	.06	.09
Mean	16.89	5.16	1.81	.042	.053	.091

TABLE 3 - Continued

Data No.	Ave. Punctae per field of .09 mm^2 (10-field mean) Umbo	Mid	Margin	Shell Thickness (mm) Umbo	Mid	Margin
D- 1	11.5 (10-13)		4.4 (3-6)	.03		.06
D- 2	13.0 (10-17)		4.4 (4-6)	.03		.06
D- 3	12.1 (9-15)		2.9 (1-5)	.03		.06
D- 4	12.8 (9-15)		2.3 (0-4)	.04		.06
D- 5	13.3 (10-16)		2.2 (1-3)	.04		.06
D- 6	15.1 (11-19)		2.5 (1-3)	.03		.07
D- 7	14.5 (11-19)		2.4 (1-4)	.03		.05
D- 8	13.0 (11-16)		2.5 (1-4)	.03		.07
D- 9	13.9 (12-16)		2.1 (1-3)	.03		.05
D-10	13.3 (11-16)		2.5 (1-5)	.03		.06
Mean	13.25		2.83	.032		.060

TABLE 3 - Continued

Data No.	Ave. Punctae per field of .09 mm^2 (10-field mean)			Shell Thickness (mm)		
	Umbo	Mid	Margin	Umbo	Mid	Margin
Y- 1	7.0 (6- 8)				.02	
Y- 2	---				.02	
Y- 3	7.3 (6-10)				.01	
Y- 4	7.7 (6- 9)				.02	
Y- 5	6.7 (5- 8)				.02	
Y- 6	6.9 (5-10)				.02	
Y- 7	6.5 (5- 8)				.02	
Y- 8	---				.02	
Y- 9	---				.02	
Y-10	7.0 (5- 9)				.02	
Mean	7.01				.019	

TABLE 4

OXYGEN-UPTAKE OF SUBMERGED ACTIVE INDIVIDUALS AT 15° C.

(Respirometer A)

Exp. No.	Duration and Activity*	Clam Wt. (mgs)	Dry Wt. (mgs)	H_2O Content (mgs)	% H_2O of Clam Wt.	STP µl O_2/hr/clam	STP µl O_2/hr/mg Clam Wt.
20	2' M	44.1	12.7	31.4	71.2	1.49	.034
22	2' S	53.4	13.6	39.8	74.5	1.13	.021
47	4' S	44.3	11.3	33.0	74.5	.64	.014
48	2' M	58.6	16.5	42.1	71.6	2.32	.040
49	40" M	44.2	12.2	32.0	72.4	1.82	.041
50	1' M	31.0	7.2	23.8	76.8	1.02	.033
51	2' M	69.8	18.5	51.3	73.5	3.11	.045
52	1' S	48.9	12.1	36.8	75.3	1.60	.033
53	2' M	60.0	16.9	43.1	71.8	2.65	.044
54	80" M 40" S	73.1	16.6	56.5	77.3	.77	.011
55	2' M	48.8	12.3	36.5	74.8	1.10	.023
56	2' M	46.5	12.6	33.9	72.9	.95	.020
57	1' S	49.0	12.8	36.2	73.9	1.17	.024
58	2' M	46.0	12.4	33.6	73.0	1.85	.040
59	2' M	43.7	11.8	31.9	72.9	2.07	.047
Means		50.76	13.30	37.45	73.76	1.58	.0313

*Activity: M = moving and siphoning
S = siphoning only

µl O_2/hr/mg clam wt.
S.D. = .01170
S.E. = .003021

TABLE 5

OXYGEN-UPTAKE OF SUBMERGED ACTIVE INDIVIDUALS AT 20° C.

(Respirometer A)

Exp. No.	Duration and Activity*	Clam Wt. (mgs)	Dry Wt. (mgs)	H_2O Content (mgs)	% H_2O of Clam Wt.	STP µl O_2/hr/clam	STP µl O_2/hr/mg Clam Wt.
109	3' M	42.3	10.7	31.6	74.7	2.03	.048
110	2' M	41.0	11.2	29.8	72.7	1.58	.039
111	3' M	44.3	11.7	32.6	73.6	1.70	.038
112	3' M	40.1	11.1	29.0	72.3	1.61	.040
113	3' M	48.4	12.8	35.6	73.6	1.68	.035
114	1' 20" M	38.8	9.7	29.1	75.0	1.98	.051
115	3' 30" M	40.7	11.0	29.7	73.0	1.84	.045
116	2' S	38.8	9.5	29.3	75.5	.85	.022
117	2' S	45.2	12.1	33.1	73.2	.98	.022
118	1' S	71.0	15.6	55.4	78.0	2.00	.028
119	1' M	49.4	12.6	36.8	74.5	2.28	.046
120	2' M	60.6	16.0	44.6	73.6	3.30	.054
121	55" M	58.2	14.2	44.0	75.6	2.36	.041
122	25" M 10" S	59.5	15.8	43.7	73.4	3.20	.054
123	40" M 20" S	38.5	10.5	28.0	72.7	1.93	.050
Means		47.79	12.30	35.49	74.09	1.96	.0409

*Activity: M = moving and siphoning
S = siphoning only

µl O_2/hr/mg clam wt.
S.D. = .01049
S.E. = .002708

TABLE 6

OXYGEN-UPTAKE OF SUBMERGED ACTIVE INDIVIDUALS AT 25° C.

(Respirometer A)

Exp. No.	Duration and Activity*	Clam Wt. (mgs)	Dry Wt. (mgs)	H_2O Content (mgs)	% H_2O of Clam Wt.	STP µl O_2/ hr/clam	STP µl O_2/ hr/mg Clam Wt.
162	2' M 30"	67.4	16.8	50.6	75.1	3.77	.056
163	1' M	65.2	15.3	49.9	76.5	4.17	.064
164	1' M 45"	63.4	15.5	47.9	75.6	3.98	.063
165	1' M 30"	49.5	13.3	36.2	73.1	3.18	.064
176	1' M	80.3	19.2	61.1	76.1	3.62	.045
177	45" M 15" S	46.5	12.2	34.3	73.8	2.17	.047
178	1' S	55.2	13.2	42.0	76.1	1.62	.029
179	1' S	40.8	9.6	31.2	76.5	1.48	.036
180	1' S	46.5	11.1	35.4	76.1	2.72	.058
181	25" S 35" M	46.0	10.8	35.2	76.5	1.97	.043
182	40" M 10" S	44.7	11.2	33.5	74.9	2.70	.060
183	22" M	53.7	12.6	41.1	76.5	3.34	.062
184	40" M	54.2	12.5	41.7	76.9	2.93	.054
185	1' S	60.5	13.8	46.7	77.2	2.17	.036
186	1' S	51.9	13.3	38.6	74.4	2.45	.047
187	1' S	75.6	19.3	56.3	74.5	4.17	.055

TABLE 6 - Continued

Exp. No.	Duration and Activity*	Clam Wt. (mgs)	Dry Wt. (mgs)	H_2O Content (mgs)	% H_2O of Clam Wt.	STP µl O_2/hr/clam	STP µl O_2/hr/mg Clam Wt.
188	1' S	47.6	11.5	36.1	75.8	2.24	.047
Means		55.82	13.60	42.22	75.62	2.86	.0504

*Activity: M = moving and siphoning
S = siphoning only

µl O_2/hr/mg clam wt.
S.D. = .01078
S.E. = .002614

TABLE 7

OXYGEN-UPTAKE OF SUBMERGED ACTIVE INDIVIDUALS AT 30° C.

(Respirometer A)

Exp. No.	Duration and Activity*	Clam Wt. (mgs)	Dry Wt. (mgs)	H_2O Content (mgs)	% H_2O of Clam Wt.	STP µl O_2/hr/clam	STP µl O_2/hr/mg Clam Wt.
220	1' S	70.5	19.7	50.8	72.1	4.13	.059
221	2' M	53.0	14.7	38.3	72.3	3.79	.072
222	2' M	51.6	14.1	37.5	72.6	4.72	.091
223	3' S	75.0	20.7	54.3	72.4	5.59	.075
244	5" M 55" S	55.0	13.0	42.0	76.4	3.27	.059
245	23" M	37.0	8.8	28.2	76.2	2.58	.070
246	35" S	77.2	18.9	58.3	75.5	4.14	.054
247	30" S	51.1	12.8	38.3	74.9	4.19	.082
248	15" S 15" M	57.4	15.3	42.1	73.3	4.85	.084
249	30" M	58.8	14.6	44.2	75.2	3.39	.058
250	30" S	63.6	14.7	48.9	76.9	4.06	.064
251	30" S	60.2	13.9	46.3	76.9	3.53	.059
252	30" S	50.6	12.5	38.1	75.3	3.79	.075
Means		58.54	14.90	43.64	74.62	4.00	.0694

*Activity: M = moving and siphoning
S = siphoning only

µl O_2/hr/mg clam wt.
S.D. = .01162
S.E. = .003222

TABLE 8

OXYGEN CONSUMPTION OF ACTIVE INDIVIDUALS OF *SPHAERIUM OCCIDENTALE* PRIME AT 15° C.

(Respirometer B)

Exp. No.	Clam Wt. (mgs)	Blank ($\mu l\ O_2$/ hr)	STP Clam-Blank ($\mu l\ O_2$/hr)	STP $\mu l\ O_2$/mg Clam Wt./ hr
NM-15-1	53.1	.086	1.717	.032
NM-15-2	50.8	.054	1.566	.031
NM-15-7	56.5	.194	1.588	.028
NM-15-10	53.9	.005	1.852	.034
NM-15-11	53.0	.043	1.134	.021
NM-15-12	58.1	.021	1.577	.027
Mean of 6 clams	54.2	.067	1.572	.029
NM-15-3	62.9	.140	1.944	.031
NM-15-8	62.0	.135	1.593	.026
NM-15-9	67.5	.216	1.674	.025
NM-15-16	67.4	.118	1.728	.026
NM-15-17	65.6	.086	1.534	.023
Mean of 5 clams	64.2	.139	1.695	.026
NM-15-4	43.2	.021	1.187	.027
NM-15-5	44.9	.036	1.152	.026
NM-15-6	44.4	.100	1.250	.028
NM-15-13	40.0	.000	0.939	.023
NM-15-14	46.0	.000	1.242	.027
Mean of 5 clams	43.7	.031	1.154	.026

TABLE 8 - Continued

Exp. No.	Clam Wt. (mgs)	Blank (µl O_2/ hr)	STP Clam-Blank (µl O_2/hr)	STP µl O_2/mg Clam Wt./ hr
Mean of 16 clams	54.33	.078	1.479	.027

All clams moving and siphoning

µl O_2/mg clam wt./hr

s of .027 = .0035
S.E. = .0009

TABLE 9

OXYGEN CONSUMPTION OF ACTIVE INDIVIDUALS OF SPHAERIUM OCCIDENTALE PRIME AT 20° C.

(Respirometer B)

Exp. No.	Clam Wt. (mgs)	Blank ($\mu l\ O_2$/ hr)	STP Clam-Blank ($\mu l\ O_2$/hr)	STP $\mu l\ O_2$/mg Clam Wt./ hr
NM-20-2	56.7	.084	2.207	.039
NM-20-3	54.2	.026	2.560	.047
NM-20-4	56.0	.000	2.587	.046
NM-20-7	52.1	.079	2.191	.042
NM-20-9	55.7	.038	2.179	.039
Mean of 5 clams	54.9	.045	2.345	.042
NM-20-6	64.1	.000	3.325	.052
NM-20-11	68.4	.052	3.094	.045
NM-20-14	65.9	.000	2.904	.044
NM-20-15	65.0	.084	3.010	.046
NM-20-16	64.2	.158	2.446	.038
Mean of 5 clams	65.5	.059	2.956	.045
NM-20-5	40.0	.084	1.617	.040
NM-20-8	47.6	.052	2.269	.048
NM-20-10	49.4	.010	2.207	.045
NM-20-12	44.8	.042	1.879	.042
NM-20-13	44.8	.026	2.107	.047
Mean of 5 clams	45.3	.043	2.016	.044

TABLE 9 - Continued

Exp. No.	Clam Wt. (mgs)	Blank (μl O_2/ hr)	STP Clam-Blank (μl O_2/hr)	STP μl O_2/mg Clam Wt./ hr
Mean of 15 clams	55.26	.049	2.439	.044

All clams moving and siphoning

μl O_2/mg clam wt./hr

s of .044 = .0038
S.E. = .0010

TABLE 10

OXYGEN CONSUMPTION OF ACTIVE INDIVIDUALS OF SPHAERIUM OCCIDENTALE PRIME AT 25° C.

(Respirometer B)

Exp. No.	Clam Wt. (mgs)	Blank (μl O_2/ hr)	STP Clam-Blank (μl O_2/hr)	STP μl O_2/mg Clam Wt./ hr
NM-25-4	62.1	.116	3.939	.063
NM-25-7	65.5	.119	3.788	.058
NM-25-8	62.2	.337	5.682	.091
NM-25-15	66.8	.211	4.857	.073
NM-25-16	66.5	.190	4.836	.073
Mean of 5 clams	64.6	.195	4.620	.072
NM-21-1	52.1	.380	3.949	.076
NM-25-2	54.0	.105	3.600	.067
NM-25-5	55.3	.331	4.051	.073
NM-25-9	58.3	.337	4.108	.070
NM-25-10	53.6	.360	3.790	.071
Mean of 5 clams	54.7	.303	3.899	.071
NM-25-3	44.1	.010	2.438	.055
NM-25-6	48.8	.116	3.791	.078
NM-25-11	42.3	.095	3.125	.074
NM-25-13	42.2	.316	3.564	.084
NM-25-14	43.2	.000	3.109	.072
NM-25-17	41.4	.295	2.714	.066
NM-25-18	42.3	.116	2.967	.070

TABLE 10 - Continued

Exp. No.	Clam Wt. (mgs)	Blank (μl O_2/ hr)	STP Clam-Blank (μl O_2/hr)	STP μl O_2/mg Clam Wt./ hr
Mean of 7 clams	43.5	.135	3.101	.071
Mean of 17 clams	52.98	.202	3.783	.071

All clams moving and siphoning

μl O_2/mg clam wt./hr

s of .071 = .0083
S.E. = .0021

TABLE 11

OXYGEN-UPTAKE OF MOIST-SURFACE INACTIVE INDIVIDUALS AT 15° C.

(Respirometer B)

Exp. No.	Duration (hrs)	Clam Wt. (mgs)	Dry Wt. (mgs)	H_2O Content (mgs)	% H_2O of Clam Wt.	STP µl O_2/ hr/clam	STP µl O_2/ hr/mg Clam Wt.
14	4	47.0	13.6	33.4	71.1	.281	.006
15	4	72.3	17.9	54.4	75.2	.227	.003
16	4	64.5	16.7	47.8	74.1	.335	.005
17	8	57.4	14.5	42.9	74.7	.153	.003
18	6	57.3	15.8	41.5	72.4	.231	.004
19	4	62.4	15.2	47.2	75.6	.165	.003
35	4	46.1	13.1	33.0	71.6	.156	.003
36	4	37.2	10.8	26.4	71.0	.116	.003
37	4	83.9	20.6	63.3	75.4	.270	.003
38	4	59.0	15.3	43.7	74.1	.243	.004
39	4	44.3	12.5	31.8	71.8	.151	.003
40	3¼	73.0	20.4	52.6	72.1	.353	.005
41	4	69.0	18.4	50.6	73.3	.253	.004
42	4	44.2	14.5	29.7	67.2	.275	.006
43	4	47.6	12.5	35.1	73.7	.210	.004
44	4	59.7	16.4	43.3	72.5	.265	.004
46	4½	54.4	14.9	39.5	72.6	.266	.005
Means	4.34	57.61	15.48	42.13	72.85	.232	.0040

µl O_2/hr/mg clam wt.
S.D. = .00106
S.E. = .000257

TABLE 12

OXYGEN-UPTAKE OF MOIST-SURFACE INACTIVE INDIVIDUALS AT 20° C.

(Respirometer B)

Exp. No.	Duration (hrs)	Clam Wt. (mgs)	Dry Wt. (mgs)	H_2O Content (mgs)	% H_2O of Clam Wt.	STP µl O_2/ hr/clam	STP µl O_2/ hr/mg Clam Wt.
86	4	71.5	17.7	53.8	75.2	.381	.005
87	4	70.2	17.7	52.5	74.8	.381	.005
88	4	48.7	13.4	35.3	72.5	.135	.003
89	4	45.1	12.5	32.6	72.3	.328	.007
90	5	47.3	13.1	34.2	72.3	.355	.008
91	4	56.2	14.2	42.0	74.7	.253	.005
92	4	46.9	13.3	33.6	71.6	.302	.006
93	4	48.3	12.5	35.8	74.1	.175	.004
94	4	61.5	16.1	45.4	73.8	.178	.003
95	6	44.5	13.0	31.5	70.8	.233	.005
96	4	54.5	16.7	37.8	69.4	.352	.006
97	4	45.2	11.8	33.4	73.9	.198	.004
98	6	36.2	9.8	26.4	72.9	.152	.004
99	4	50.6	13.8	36.8	72.7	.249	.005
100	5	50.8	12.8	38.0	74.8	.227	.004
101	4	69.0	17.9	51.1	74.1	.280	.004
102	4	42.6	11.7	30.9	72.5	.230	.005
103	3½	45.2	13.0	32.2	71.2	.225	.005
104	4	60.8	14.9	45.9	75.5	.199	.003
105	3	51.2	12.7	38.5	75.2	.194	.004

TABLE 12 - Continued

Exp. No.	Duration (hrs)	Clam Wt. (mgs)	Dry Wt. (mgs)	H_2O Content (mgs)	% H_2O of Clam Wt.	STP µl O_2/ hr/clam	STP µl O_2/ hr/mg Clam Wt.
106	3	55.4	13.5	41.9	75.6	.226	.004
107	4	36.7	9.6	27.1	73.8	.206	.006
Means	4.16	51.75	13.71	38.03	73.35	.248	.0048

µl O_2/hr/mg clam wt.
S.D. = .00127
S.E. = .000271

TABLE 13

OXYGEN-UPTAKE OF MOIST-SURFACE INACTIVE INDIVIDUALS AT 25° C.

(Respirometer B)

Exp. No.	Duration (hrs)	Clam Wt. (mgs)	Dry Wt. (mgs)	H_2O Content (mgs)	% H_2O of Clam Wt.	STP µl O_2/ hr/clam	STP µl O_2/ hr/mg Clam Wt.
137	8	58.2	15.7	42.5	73.0	.456	.008
138	4½	40.1	10.7	29.4	73.3	.291	.007
140	2	65.2	15.3	49.9	76.5	.438	.007
141	6	50.0	12.7	37.3	74.6	.251	.005
143	8	63.4	15.5	47.9	75.6	.712	.011
145	10	54.1	14.3	39.8	73.6	.474	.009
146	4	57.7	14.0	43.7	75.7	.368	.006
147	11	54.2	13.9	40.3	74.4	.309	.006
148	10	54.4	14.5	39.9	73.3	.295	.005
149	6	52.6	12.9	39.7	75.5	.375	.007
150	6	46.9	11.4	35.5	75.7	.429	.009
Means	6.86	54.26	13.72	40.54	74.66	.400	.0073

µl O_2/hr/mg clam wt.
S.D. = .00185
S.E. = .000557

TABLE 14

OXYGEN-UPTAKE OF MOIST-SURFACE INACTIVE INDIVIDUALS AT 30° C.

(Respirometer B)

Exp. No.	Duration (hrs)	Clam Wt. (mgs)	Dry Wt. (mgs)	H_2O Content (mgs)	% H_2O of Clam Wt.	STP µl O_2/hr/clam	STP µl O_2/hr/mg Clam Wt.
204	4	73.3	21.2	52.1	71.1	.617	.008
205	4	90.2	24.0	66.2	73.4	.813	.009
206	4	52.5	16.2	36.3	69.1	.655	.012
207	4	53.2	14.4	38.8	72.9	.735	.014
208	4½	45.1	13.5	31.6	70.0	.580	.013
209	4	55.5	17.1	38.4	69.2	.790	.014
210	4	50.0	14.2	35.8	71.6	.697	.014
211	4	60.3	15.5	44.8	74.3	.620	.010
212	4	51.6	14.9	36.7	71.1	.571	.011
213	4	67.3	20.6	46.7	69.4	.568	.008
214	4	65.0	16.8	48.2	74.2	.812	.012
215	4	58.9	15.3	43.6	74.0	.685	.012
216	4	63.3	16.8	46.5	73.5	.797	.013
217	4	55.1	15.0	40.1	72.8	.463	.008
218	5	51.4	16.1	35.3	68.7	.516	.010
238	4	52.3	12.8	39.5	75.5	.411	.008
239	4	54.6	13.5	41.1	75.3	.528	.010
240	4	47.0	11.4	35.6	75.7	.262	.006
241	4	55.8	13.5	42.3	75.8	.575	.010
242	4	30.6	7.8	22.8	74.5	.247	.008

TABLE 14 - Continued

Exp. No.	Duration (hrs)	Clam Wt. (mgs)	Dry Wt. (mgs)	H_2O Content (mgs)	% H_2O of Clam Wt.	STP $\mu l\ O_2$/ hr/clam	STP $\mu l\ O_2$/ hr/mg Clam Wt.
243	4	56.3	14.3	42.0	74.6	.411	.007
Means	4.07	56.63	15.47	41.16	72.70	.588	.0103

$\mu l\ O_2$/hr/mg clam wt.
S.D. = .00248
S.E. = .000541

TABLE 15

OXYGEN-UPTAKE OF GROUPS OF CLAMS AT 25° C. IN MOIST-SURFACE CONDITION AND RELATIVE TO WEIGHT OF ANIMALS

(Respirometer B)

Exp. No.	No. of Clams	Agg. Wt. (mgs)	Ave. Clam Wt. (mgs)	Duration (hrs)	STP Agg. µl O_2/ hr	STP µl O_2/ ave. clam/ hr	STP µl O_2/ mg clam wt/hr
1	18	170.5	9.5	3	4.072	.226	.024
2	25	130.4	5.2	2	4.360	.174	.033
3	30	82.0	2.7	2	5.237	.175	.064
4	10	163.6	16.4	2	1.938	.194	.012
5	5	310.0	62.0	2	3.194	.639	.010
6	5	253.0	50.6	2	2.580	.516	.010
7	5	137.0	27.4	2	1.462	.292	.011
8	7	237.2	33.9	2	3.539	.505	.015
9	7	178.5	25.5	2	2.417	.345	.014
10	7	133.6	19.1	2	1.958	.280	.015
11	5	359.7	71.9	2	2.848	.570	.010
12	7	238.8	34.1	3	2.986	.427	.013
13	8	178.4	22.3	3.5	2.002	.250	.011
14	6	362.0	60.3	2	2.668	.517	.007
15	5	279.0	55.8	2	1.935	.387	.007
16	6	447.5	74.6	2	2.735	.456	.006
17	9	155.3	17.3	3	2.064	.229	.013
18	5	325.3	65.1	2	2.346	.469	.007
19	19	31.0	1.6	2	.547	.027	.018
20	5	253.9	50.8	2	2.295	.459	.009

TABLE 15 - Continued

Exp. No.	No. of Clams	Agg. Wt. (mgs)	Ave. Clam Wt. (mgs)	Duration (hrs)	STP Agg. µl O_2/ hr	STP µl O_2/ ave. clam/ hr	STP µl O_2/ mg clam wt/hr
21	5	253.7	50.7	2	2.322	.464	.009
22	7	317.5	45.4	2	2.477	.354	.008
23	5	373.0	74.6	2	2.812	.562	.008
24	10	375.0	37.5	2	4.644	.464	.012
25	5	344.3	68.9	2	2.142	.428	.006
26	6	308.6	51.4	2	2.550	.425	.008
27	10	255.0	25.5	2	3.122	.312	.012
28	13	118.5	9.1	1.75	1.946	.150	.016
29	7	237.6	33.9	2	2.182	.312	.009
30	5	307.0	61.4	2	2.265	.453	.007
31	5	214.2	42.8	2	2.322	.464	.011
32	7	153.8	21.9	2	1.775	.254	.012
33	10	119.1	11.9	2.75	1.914	.191	.016
34	4	270.0	67.5	2	2.167	.542	.008
35	5	217.5	43.5	2	1.393	.279	.006
36	15	81.6	5.4	2	1.171	.078	.014
37	3	242.0	80.7	2	2.297	.766	.009
38	3	217.3	72.4	2	1.780	.593	.008
39	4	188.0	47.0	2	1.455	.364	.008
40	5	261.0	52.2	2	1.651	.330	.006
41	5	254.0	50.8	2	1.496	.299	.006
42	5	234.0	46.8	2	1.548	.310	.007
43	6	259.0	43.2	2	2.528	.421	.010

TABLE 15 - Continued

Exp. No.	No. of Clams	Agg. Wt. (mgs)	Ave. Clam Wt. (mgs)	Duration (hrs)	STP Agg. µl O_2/ hr	STP µl O_2/ ave. clam/ hr	STP µl O_2/ mg clam wt/hr
44	6	211.0	35.2	2	1.931	.322	.009
45	3	258.0	86.0	2	1.301	.434	.005
46	4	299.0	74.8	2	1.999	.500	.007
47	7	301.4	43.1	2	2.219	.317	.007
48	15	214.0	14.3	2	2.036	.136	.010
49	16	135.0	8.4	2	2.036	.127	.015
50	3	238.0	74.0	2	2.088	.696	.009

TABLE 16

OXYGEN-UPTAKE OF GROUPS OF CLAMS AT 25° C. IN DRY-SURFACE CONDITION AND RELATIVE TO WEIGHT OF ANIMALS

(Respirometer B)

Exp. No.	No. of Clams	Agg. Wt. (mgs)	Ave. Clam Wt. (mgs)	Duration (hrs)	STP Agg. µl O_2/ hr	STP µl O_2/ ave. clam/ hr	STP µl O_2/ mg clam wt/hr
1	18	170.5	9.5	5	1.958	.109	.011
2	25	130.4	5.2	4	1.548	.062	.019
3	30	82.0	2.7	2	.810	.027	.010
4	10	163.6	16.4	2	1.530	.153	.009
5	5	310.0	62.0	2	2.415	.483	.008
6	5	253.0	50.6	2	1.945	.452	.008
7	5	137.0	27.4	2	1.096	.219	.008
8	7	237.2	33.9	2	2.427	.347	.010
9	7	178.5	25.5	2	2.093	.299	.012
10	7	133.6	19.1	2	1.479	.211	.011
11	5	359.7	71.9	3	2.459	.492	.007
12	7	238.8	34.1	2	2.884	.412	.012
13	8	178.4	22.3	2	1.816	.227	.010
14	6	362.0	60.3	2	2.234	.372	.006
15	5	279.0	55.8	2	1.641	.328	.006
16	6	447.5	74.6	2	2.477	.413	.006
17	9	155.3	17.3	3	1.307	.145	.008
18	5	325.3	65.1	2	1.811	.342	.006
19	19	31.0	1.6	2	.310	.016	.010
20	5	253.9	50.8	2	1.744	.349	.007

TABLE 16 - Continued

Exp. No.	No. of Clams	Agg. Wt. (mgs)	Ave. Clam Wt. (mgs)	Duration (hrs)	STP Agg. µl O_2/ hr	STP µl O_2/ ave. clam/ hr	STP µl O_2/ mg clam wt/hr
21	5	253.7	50.7	2.5	1.909	.382	.008
22	7	317.5	45.4	3	2.446	.349	.008
23	5	373.0	74.6	2	2.503	.501	.007
24	10	375.0	37.5	2.5	2.278	.228	.006
25	5	344.3	68.9	2	1.884	.320	.005
26	6	308.6	51.4	2.16	2.306	.384	.007
27	10	255.0	25.5	2	3.044	.304	.012
28	13	118.5	9.1	2	1.445	.111	.012
29	7	237.6	33.9	2	1.921	.274	.008
30	5	307.0	61.4	2	2.064	.413	.007
31	5	214.2	42.8	2	2.054	.411	.010
32	7	153.8	21.9	2	1.581	.226	.010
33	10	119.1	11.9	3.5	1.238	.124	.010
34	4	270.0	67.5	2	1.780	.445	.007
35	5	217.5	43.5	2	1.496	.299	.007
36	15	81.6	5.4	2	.949	.063	.012
37	3	242.0	80.7	2	1.592	.531	.007
38	3	217.3	72.4	2	1.316	.439	.006
39	4	188.0	47.0	2	1.342	.336	.007
40	5	261.0	52.2	2	1.445	.289	.006
41	5	254.0	50.8	2	1.455	.291	.006
42	5	234.0	46.8	2	1.754	.351	.007
43	6	259.0	43.2	2	1.816	.303	.007

TABLE 16 - Continued

Exp. No.	No. of Clams	Agg. Wt. (mgs)	Ave. Clam Wt. (mgs)	Duration (hrs)	STP Agg. µl O_2/ hr	STP µl O_2/ ave. clam/ hr	STP µl O_2/ mg clam wt/hr
44	6	211.0	35.2	2	1.921	.320	.009
45	3	258.0	86.0	2	1.326	.442	.005
46	4	299.0	74.8	2	1.811	.453	.006
47	7	301.4	43.1	2	2.038	.291	.007
48	15	214.0	14.3	2	1.462	.097	.007
49	16	135.0	8.4	2	1.227	.077	.009
50	3	238.0	74.0	2	1.514	.505	.006

TABLE 17

OXYGEN-UPTAKE OF GROUPS OF CLAMS AT 25° C. IN MOIST-SURFACE CONDITION AND RELATIVE TO VOLUME OF ANIMALS

(Respirometer B)

Exp. No.	No. of Clams	Agg. Vol. (µls)	Ave. Clam Vol. (µls)	STP Agg. µl O_2/hr	STP Ave. µl O_2/ clam/ hr	Ave. Vol. 2/3	STP Ave. µl O_2/ave. clam vol 2/3 (µls)/hr
1	18	145	8.1	4.072	.226	4.04	.056
2	25	108	4.3	4.360	.174	2.66	.065
3	30	68	2.3	5.237	.175	1.74	.101
4	10	139	13.9	1.938	.194	5.76	.034
5	5	263	52.6	3.194	.639	14.06	.045
6	5	210	42.0	2.580	.516	12.11	.043
7	5	117	23.4	1.462	.292	8.18	.035
8	7	201	28.7	3.539	.505	9.36	.054
9	7	156	22.3	2.417	.345	7.90	.044
10	7	115	16.4	1.958	.280	6.45	.043
11	5	296	59.2	2.848	.570	17.31	.033
12	7	180	25.7	2.986	.427	8.70	.049
13	8	177	22.1	2.002	.250	7.90	.032
14	6	299	49.8	2.668	.517	13.54	.038
15	5	248	49.6	1.935	.387	13.47	.029
16	6	389	64.8	2.735	.456	16.16	.028
17	9	134	14.9	2.064	.229	6.05	.038
18	5	285	57.0	2.346	.469	14.82	.032
19	19	28	1.5	.547	.027	1.30	.021

TABLE 17 - Continued

Exp. No.	No. of Clams	Agg. Vol. (µls)	Ave. Clam Vol. (µls)	STP Agg. µl O_2/hr	STP Ave. µl O_2/ clam/ hr	Ave. Vol. 2/3	STP Ave. µl O_2/ave. clam vol 2/3 (µls)/hr
20	5	223	44.6	2.295	.459	12.60	.036
21	5	220	44.0	2.322	.464	12.46	.037
22	7	280	40.0	2.477	.354	11.70	.030
23	5	322	64.4	2.812	.562	16.08	.035
24	10	328	32.8	4.644	.464	10.24	.045
25	5	307	61.4	2.142	.428	15.60	.027
26	6	268	44.7	2.550	.425	12.60	.034
27	10	221	22.1	3.122	.312	7.90	.039
28	13	101	7.8	1.946	.150	3.92	.038
29	7	203	29.0	2.182	.312	9.42	.033
30	5	263	52.6	2.265	.453	14.06	.032
31	5	187	37.4	2.322	.464	11.16	.042
32	7	138	19.7	1.775	.254	7.29	.035
33	10	101	10.1	1.914	.191	4.67	.041
34	4	229	57.3	2.167	.542	14.82	.037
35	5	189	37.8	1.393	.279	11.29	.025
36	15	70	4.7	1.171	.078	2.82	.028
37	3	216	72.0	2.297	.766	17.31	.044
38	3	183	61.0	1.780	.593	15.52	.038
39	4	164	41.0	1.455	.364	11.90	.031
40	5	237	47.4	1.651	.330	13.10	.025
41	5	217	43.4	1.496	.299	12.32	.024

TABLE 17 - Continued

Exp. No.	No. of Clams	Agg. Vol. (µls)	Ave. Clam Vol. (µls)	STP Agg. µl O_2/hr	STP Ave. µl O_2/ clam/ hr	Ave. Vol. 2/3	STP Ave. µl O_2/ave. clam vol 2/3 (µls)/hr
42	5	201	40.2	1.548	.310	11.76	.026
43	6	219	36.5	2.528	.421	11.02	.038
44	6	177	29.5	1.931	.322	9.55	.034
45	3	207	69.0	1.301	.434	16.81	.026
46	4	259	64.8	1.999	.500	16.16	.031
47	7	271	38.7	2.219	.317	11.42	.028
48	15	187	12.5	2.036	.136	5.38	.025
49	16	117	7.3	2.036	.127	3.76	.034
50	3	192	64.0	2.088	.696	16.00	.044

TABLE 18

OXYGEN-UPTAKE OF GROUPS OF CLAMS AT 25° C. IN DRY-SURFACE CONDITION AND RELATIVE TO VOLUME OF ANIMALS

(Respirometer B)

Exp. No.	No. of Clams	Agg. Vol. (µls)	Ave. Clam Vol. (µls)	STP Agg. µl O_2/hr	STP Ave. µl O_2/ clam/ hr	Ave. Vol. 2/3	STP Ave. µl O_2/ave. clam vol 2/3 (µls)/hr
1	18	145	8.1	1.958	.109	4.04	.027
2	25	108	4.3	1.548	.062	2.66	.023
3	30	68	2.3	.810	.027	1.74	.016
4	10	139	13.9	1.530	.153	5.76	.027
5	5	263	52.6	2.415	.483	14.06	.034
6	5	210	42.0	1.945	.452	12.11	.038
7	5	117	23.4	1.096	.219	8.18	.027
8	7	201	28.7	2.427	.347	9.36	.037
9	7	156	22.3	2.093	.299	7.90	.038
10	7	115	16.4	1.479	.211	6.45	.033
11	5	296	59.2	2.459	.492	17.31	.029
12	7	180	25.7	2.884	.412	8.70	.047
13	8	177	22.1	1.816	.227	7.90	.029
14	6	299	49.8	2.234	.372	13.54	.027
15	5	248	49.6	1.641	.328	13.47	.024
16	6	389	64.8	2.477	.413	16.16	.026
17	9	134	14.9	1.307	.145	6.05	.024
18	5	285	57.0	1.811	.342	14.82	.023
19	19	28	1.5	.310	.016	1.30	.012

TABLE 18 - Continued

Exp. No.	No. of Clams	Agg. Vol. (µls)	Ave. Clam Vol. (µls)	STP Agg. µl O_2/hr	STP Ave. µl O_2/ clam/ hr	Ave. Vol. 2/3	STP Ave. µl O_2/ave. clam vol 2/3 (µls)/hr
20	5	223	44.6	1.744	.349	12.60	.028
21	5	220	44.0	1.909	.382	12.46	.031
22	7	280	40.0	2.446	.349	11.70	.030
23	5	322	64.4	2.503	.501	16.08	.031
24	10	328	32.8	2.278	.228	10.24	.022
25	5	307	61.4	1.884	.320	15.60	.021
26	6	268	44.7	2.306	.384	12.60	.030
27	10	221	22.1	3.044	.304	7.90	.038
28	13	101	7.8	1.445	.111	3.92	.028
29	7	203	29.0	1.921	.274	9.42	.029
30	5	263	52.6	2.064	.413	14.06	.029
31	5	187	37.4	2.054	.411	11.16	.037
32	7	138	19.7	1.581	.226	7.29	.031
33	10	101	10.1	1.238	.124	4.67	.027
34	4	229	57.3	1.780	.445	14.82	.030
35	5	189	37.8	1.496	.299	11.29	.026
36	15	70	4.7	.949	.063	2.82	.022
37	3	216	72.0	1.592	.531	17.31	.031
38	3	183	61.0	1.316	.439	15.52	.028
39	4	164	47.0	1.342	.336	11.90	.028
40	5	237	47.4	1.445	.289	13.10	.022
41	5	217	43.4	1.455	.291	12.32	.024

TABLE 18 - Continued

Exp. No.	No. of Clams	Agg. Vol. (µls)	Ave. Clam Vol. (µls)	STP Agg. µl O_2/hr	STP Ave. µl O_2/ clam/ hr	Ave. Vol. 2/3	STP Ave. µl O_2/ave. clam vol 2/3 (µls)/hr
42	5	201	40.2	1.754	.351	11.76	.030
43	6	219	36.5	1.816	.303	11.02	.027
44	6	177	35.2	1.921	.320	9.55	.034
45	3	207	69.0	1.326	.442	16.81	.026
46	4	259	64.8	1.811	.453	16.16	.028
47	7	271	38.7	2.038	.291	11.42	.025
48	15	187	12.5	1.462	.097	5.38	.018
49	16	117	7.3	1.227	.077	3.76	.020
50	3	192	64.0	1.514	.505	16.00	.032

TABLE 19

WEIGHT LOSS AND LONGEVITY OF *SPHAERIUM OCCIDENTALE* IN AN ATMOSPHERE OF 93% RELATIVE HUMIDITY AT 20° C.

(Calculated Vapor Pressure Deficit: 1.23)

Initial Weight	Des. Wt.	Δ Weight	Percent Original	Viability
25 hrs. - 1400 hrs., 15 Aug. - 1500 hrs., 16 Aug. 1961				
47	47	+ 0	100	+
51	52	+ 1	102	+
47	45	- 2	96	+
67	67	+ 0	100	+
44	43	+ 1	98	+
49	49	+ 0	100	+
81	80	- 1	99	+
47	46	- 1	98	+
42	42	+ 0	100	+
57	57	+ 0	100	+
Mean 53.2			99.3 (live)	
51 hrs. - 1400 hrs., 15 Aug. - 1700 hrs., 17 Aug. 1961				
94	95	+ 1	101	+
57	57	0	100	+
101	102	+ 1	101	+
44	44	0	100	+
70	70	0	100	+
58	58	0	100	+
85	85	0	100	+
77	71	6	92	0
63	62	1	98	+
61	59	2	97	+
Mean 71.0			99.7 (live)	
76 hrs. - 1400 hrs., 15 Aug. - 1800 hrs., 18 Aug. 1961				
64	64	0	100	+
48	47	1	98	+
75	74	1	99	+
101	101	0	100	+
53	54	+ 1	102	+
95	98	+ 3	103	+
69	70	+ 1	101	+
71	70	1	99	+
63	63	0	100	+
63	61	2	97	+
Mean 70.2			99.9 (live)	

TABLE 19 - Continued

Initial Weight	Des. Wt.	Δ Weight	Percent Original	Viability
105 hrs. - 1400 hrs., 15 Aug. - 2300 hrs., 19 Aug. 1961				
54	52	2	96	+
76	76	0	100	+
61	61	0	100	+
44	39	5	89	0
66	66	0	100	+
81	81	0	100	+
68	65	3	96	+
71	68	3	96	0
52	48	4	92	+
58	58	0	100	+
Mean 63.1			98.0 (live)	
129 hrs. - 1400 hrs., 15 Aug. - 2300 hrs., 20 Aug. 1961				
63	63	0	100	+
64	64	0	100	+
61	61	0	100	0
56	54	2	96	+
60	59	1	98	+
58	56	2	97	+
57	52	5	91	+
47	45	2	96	+
75	73	2	97	0
97	96	1	99	+
Mean 63.8			97.1 (live)	
154 hrs. - 1400 hrs., 15 Aug. - 2400 hrs., 21 Aug. 1961				
66	66	0	100	+
52	42	10	81	+
99	99	0	100	+
49	45	4	92	0
70	68	2	97	+
80	78	2	98	+
91	87	4	96	+
67	66	1	99	+
Mean 71.8			95.9 (live)	

TABLE 19 - Continued

Initial Weight	Des. Wt.	Δ Weight	Percent Original	Viability
173½ hrs. - 1400 hrs., 15 Aug. - 1930 hrs., 22 Aug. 1961				
85	83	2	98	+
50	40	10	80	+
75	74	1	99	+
79	77	2	97	+
87	86	1	99	+
41	39	2	95	+
58	56	2	97	+
57	55	2	96	+
97	82	15	85	+
44	41	3	93	+
Mean 67.3			93.9 (live)	
198 hrs. - 1400 hrs., 15 Aug. - 2000 hrs., 23 Aug. 1961				
102	99	3	97	+
83	82	1	99	+
91	89	2	98	+
59	57	2	97	+
60	59	1	98	+
48	48	0	100	+
64	64	0	100	+
44	42	2	95	+
68	66	2	97	+
49	47	2	96	+
Mean 66.8			97.7 (live)	
223 hrs. - 1400 hrs., 15 Aug. - 2100 hrs., 24 Aug. 1961				
47	36	11	77	+
70	40	30	57	+
86	84	2	98	+
52	50	2	96	+
49	49	0	100	+
51	44	7	86	+
61	57	4	93	+
50	49	1	98	+
69	62	7	90	0
63	60	3	95	+
Mean 59.8			88.9 (live)	

TABLE 19 - Continued

Initial Weight	Des. Wt.	Δ Weight	Percent Original	Viability
242 hrs. - 1400 hrs., 15 Aug. - 1600 hrs., 25 Aug. 1961				
86	86	0	100	+
77	76	1	99	+
52	50	2	96	+
58	56	2	97	+
91	85	6	93	+
43	41	2	95	+
63	62	1	98	+
51	50	1	98	+
55	54	1	98	+
66	55	11	83	0
Mean 64.2			97.1 (live)	
266 hrs. - 1400 hrs., 15 Aug. - 1600 hrs., 26 Aug. 1961				
80	79	1	99	+
64	68	+ 4	106	+
89	87	2	98	+
50	49	1	98	+
40	37	3	92	+
54	52	2	96	+
73	72	1	99	+
41	40	1	98	+
55	53	2	96	+
Mean 60.7			98.0 (live)	
291 hrs. - 1400 hrs., 15 Aug. - 1700 hrs., 27 Aug. 1961				
78	68	10	87	+
51	50	1	98	+
44	43	1	98	+
60	59	1	98	+
78	76	2	97	+
57	42	15	74	0
52	48	4	92	+
66	63	3	95	+
92	90	2	98	+
45	43	2	96	+
Mean 62.3			95.4 (live)	

TABLE 19 - Continued

Initial Weight	Des. Wt.	Δ Weight	Percent Original	Viability
312 hrs. - 1400 hrs., 15 Aug. - 1400 hrs., 28 Aug. 1961				
61	61	0	100	+
65	65	0	100	+
40	34	6	85	+
49	45	4	92	+
88	80	8	91	+
59	58	1	98	+
66	63	3	95	+
30	28	2	93	+
69	62	7	40	+
52	44	8	85	+
Mean 57.9			87.9 (live)	
362 hrs. - 1400 hrs., 15 Aug. - 1600 hrs., 30 Aug. 1961				
72	69	3	96	0
71	71	0	100	+
65	63	2	97	+
94	92	2	98	+
71	69	2	97	+
53	13	40	25	0
70	48	22	69	0
68	66	2	97	+
50	47	3	94	+
64	50	14	78	0
Mean 67.8			97.2 (live)	
387½ hrs. - 1400 hrs., 15 Aug. - 1730 hrs., 31 Aug. 1961				
66	66	0	100	+
60	58	2	97	+
70	20	50	29	0
68	64	4	94	+
91	33	58	36	0
53	44	9	83	0
73	72	1	99	+
64	48	16	75	+
99	26	73	26	0
93	66	27	71	0
Mean 73.7			93.0 (live)	

TABLE 19 - Continued

Initial Weight	Des. Wt.	Δ Weight	Percent Original	Viability
413½ hrs. - 1400 hrs., 15 Aug. - 1930 hrs., 1 Sep. 1961				
63	45	18	71	0
90	88	2	98	+
63	57	6	90	0
58	53	5	91	+
65	62	3	95	+
64	42	22	66	0
49	40	9	82	+
66	63	3	95	+
50	48	2	96	+
Mean 63.1			92.8(live)	
432½ hrs. - 1400 hrs., 15 Aug. - 1430 hrs., 2 Sep. 1961				
86	75	11	87	+
73	68	5	93	+
54	55	+ 1	102	+
54	46	8	85	0
51	50	1	98	+
42	41	1	98	+
42	14	28	33	0
57	55	2	96	+
53	50	3	94	+
Mean 56.9			95.4(live)	

TABLE 20

WEIGHT LOSS AND LONGEVITY OF *SPHAERIUM OCCIDENTALE* IN AN ATMOSPHERE OF 70% RELATIVE HUMIDITY AT 20° C.

(Calculated Vapor Pressure Deficit: 5.06)

Initial Weight	Des. Wt.	Δ Weight	Percent Original	Viability
28½ hrs. - 1500 hrs., 21 Aug. - 1930 hrs., 22 Aug. 1961				
59	56	3	95	+
64	61	3	95	+
94	88	6	94	+
56	54	2	96	+
55	52	3	95	+
46	45	1	98	+
61	48	13	79	+
75	71	4	95	+
76	57	19	75	+
66	62	4	94	+
Mean 65.2			91.6(live)	
53 hrs. - 1500 hrs., 21 Aug. - 2000 hrs., 23 Aug. 1961				
52	47	5	90	+
41	39	2	95	+
67	63	4	94	+
58	55	3	95	+
52	48	4	92	+
66	57	9	86	+
64	57	7	89	+
75	69	6	92	+
63	57	6	90	+
92	74	18	80	0
Mean 63.0			91.4(live)	
78 hrs. - 1500 hrs., 21 Aug. - 2100 hrs., 24 Aug. 1961				
47	43	4	91	+
69	62	7	90	+
48	45	3	94	+
63	57	6	90	+
45	40	5	89	+
52	47	5	90	+
50	47	3	94	+
46	38	8	83	+
73	37	36	51	+
67	57	10	85	+
Mean 56.0			85.7(live)	

TABLE 20 - Continued

Initial Weight	Des. Wt.	Δ Weight	Percent Original	Viability
97 hrs. - 1500 hrs., 21 Aug. - 1600 hrs., 25 Aug. 1961				
75	68	7	91	+
63	56	7	89	+
73	65	8	89	+
54	38	16	70	0
60	56	4	93	+
71	67	4	94	+
55	50	5	91	+
62	56	6	90	+
63	56	7	89	+
72	59	13	82	+
Mean 64.8			89.8 (live)	
121 hrs. - 1500 hrs., 21 Aug. - 1600 hrs., 26 Aug. 1961				
51	42	9	82	+
62	57	5	92	+
50	46	4	92	+
56	50	6	89	+
55	49	6	89	+
39	32	7	82	+
60	51	9	85	+
50	32	18	64	+
50	46	4	92	+
84	69	15	82	0
Mean 55.7			85.2 (live)	
146 hrs. - 1500 hrs., 21 Aug. - 1700 hrs., 27 Aug. 1961				
43	39	4	91	+
62	55	7	89	+
50	44	6	88	+
69	61	8	88	+
39	35	4	90	+
53	35	18	66	+
57	53	4	93	+
58	49	9	84	+
50	43	7	86	+
48	41	7	85	+
Mean 52.9			86.0 (live)	

TABLE 20 - Continued

Initial Weight	Des. Wt.	Δ Weight	Percent Original	Viability
167 hrs. - 1500 hrs., 21 Aug. - 1400 hrs., 28 Aug. 1961				
63	52	11	83	0
47	41	6	87	+
60	53	7	88	+
56	50	6	89	+
59	48	11	81	+
53	46	7	87	+
43	35	8	81	+
65	59	6	91	+
51	44	7	86	+
Mean 55.2			86.3 (live)	
217 hrs. - 1500 hrs., 21 Aug. - 1600 hrs., 30 Aug. 1961				
52	42	10	81	+
60	52	8	87	+
67	28	39	42	0
62	46	16	74	+
78	66	12	85	+
55	42	13	76	+
50	38	12	76	+
79	65	14	82	+
70	34	36	49	0
62	47	15	76	+
Mean 63.5			79.6 (live)	
242½ hrs. - 1500 hrs., 21 Aug. - 1730 hrs., 31 Aug. 1961				
72	67	5	93	+
54	41	13	76	+
58	51	7	88	+
55	45	10	82	+
52	13	39	25	0
81	70	11	86	+
48	36	12	75	+
99	25	74	25	0
64	48	16	75	0
45	37	8	82	+
Mean 62.8			83.1 (live)	

TABLE 20 - Continued

Initial Weight	Des. Wt.	Δ Weight	Percent Original	Viability
268½ hrs. - 1500 hrs., 21 Aug. - 1930 hrs., 1 Sep. 1961				
43	34	9	79	+
30	24	6	80	+
76	66	10	87	+
61	46	15	75	+
62	50	12	81	+
64	49	15	77	+
45	20	25	44	0
70	58	12	83	0
68	57	11	84	+
50	40	10	80	+
Mean 56.9			80.4 (live)	
287½ hrs. - 1500 hrs., 21 Aug. - 1430 hrs., 2 Sep. 1961				
46	23	23	50	0
66	51	15	77	+
53	32	21	60	0
50	13	37	26	0
60	76	44	27	0
45	35	10	78	0
55	38	17	69	0
70	59	11	84	+
55	39	16	71	+
72	59	13	82	+
Mean 57.2			78.5 (live)	
368 hrs. - 1500 hrs., 21 Aug. - 2300 hrs., 5 Sep. 1961				
59	38	21	64	+
50	38	12	76	+
75	53	22	71	+
69	52	17	75	+
51	42	9	82	+
61	23	38	38	0
62	52	10	84	+
64	53	11	83	+
73	48	25	66	0
Mean 62.7			76.4 (live)	

TABLE 20 - Continued

Initial Weight	Des. Wt.	Δ Weight	Percent Original	Viability
441½ hrs. - 1500 hrs., 21 Aug. - 0030 hrs., 9 Sep. 1961				
70	59	11	84	+
44	14	30	32	0
73	39	34	53	+
38	30	8	79	+
67	49	18	73	+
65	46	19	71	+
62	33	29	53	0
68	28	40	41	0
55	16	39	29	0
58	41	17	71	+
Mean 60.0			71.8 (live)	
512 hrs. - 1500 hrs., 21 Aug. - 2300 hrs., 11 Sep. 1961				
54	19	35	35	0
43	25	18	58	+
48	27	21	56	+
54	42	12	78	+
45	35	10	78	+
70	21	49	30	0
48	33	15	69	+
82	41	41	50	0
59	44	15	75	+
64	41	23	64	+
Mean 56.7			68.3 (live)	
765 hrs. - 1500 hrs., 21 Aug. - 1200 hrs., 22 Sep. 1961				
74	50	24	68	+
46	12	34	26	0
69	17	52	25	0
47	21	26	45	0
43	10	33	23	0
38	13	25	34	0
66	20	46	30	0
64	41	23	64	0
52	25	27	48	0
Mean 55.4				

TABLE 21

WEIGHT LOSS AND LONGEVITY OF SPHAERIUM OCCIDENTALE IN AN ATMOSPHERE OF 35% RELATIVE HUMIDITY AT 20° C.

(Calculated Vapor Pressure Deficit: 11.49)

Initial Weight	Des. Wt.	Δ Weight	Percent Original	Viability
27 hrs. - 1500 hrs., 16 Aug. - 1800 hrs., 17 Aug. 1961				
39	33	6	85	+
63	50	13	79	+
59	54	5	92	+
49	46	3	94	+
74	70	4	95	+
68	60	8	88	+
95	85	10	89	+
61	56	5	92	+
80	71	9	89	+
57	51	6	89	+
Mean 64.5			89.2 (live)	
47½ hrs. - 1500 hrs., 16 Aug. - 1430 hrs., 18 Aug. 1961				
85	63	22	74	+
40	23	17	57	0
44	32	12	73	+
57	51	6	89	+
56	51	5	91	+
61	54	7	89	+
49	39	10	80	+
59	43	16	73	+
63	55	8	87	+
55	42	13	76	+
Mean 56.9			81.3 (live)	
78½ hrs. - 1500 hrs., 16 Aug. - 2130 hrs., 19 Aug. 1961				
57	46	11	81	+
69	18	51	26	0
46	28	18	61	0
84	71	13	85	+
45	39	6	87	+
80	71	9	89	+
59	47	12	80	+
64	54	10	84	+
61	46	15	75	+
65	46	19	71	+
Mean 63.0			81.5 (live)	

TABLE 21 - Continued

Initial Weight	Des. Wt.	Δ Weight	Percent Original	Viability
103 hrs. - 1500 hrs., 16 Aug. - 2200 hrs., 20 Aug. 1961				
70	30	40	43	0
56	33	23	59	+
48	17	31	36	0
77	46	31	59	0
79	70	9	89	+
52	42	10	81	0
55	44	11	80	+
83	66	17	80	0
46	36	10	78	+
64	52	12	81	+
Mean 63.0			77.4 (live)	
127 hrs. - 1500 hrs., 16 Aug. - 2200 hrs., 21 Aug. 1961				
47	19	28	40	0
76	63	13	83	+
82	62	20	76	+
47	21	26	45	0
50	41	9	82	+
54	37	17	69	+
63	41	22	65	0
71	62	9	87	+
57	18	39	32	0
52	46	6	88	+
Mean 59.9			80.8 (live)	
143 hrs. - 1500 hrs., 16 Aug. - 1400 hrs., 22 Aug. 1961				
59	26	33	44	0
83	55	28	66	0
46	10	36	22	0
40	14	26	35	0
61	38	23	62	+
62	46	16	74	+
55	39	16	71	+
70	18	52	26	0
57	24	33	42	0
Mean 59.2				

TABLE 21 - Continued

Initial Weight	Des. Wt.	Δ Weight	Percent Original	Viability
168 hrs. - 1500 hrs., 16 Aug. - 1500 hrs., 23 Aug. 1961				
62	32	30	52	0
50	14	36	28	0
75	62	13	83	+
47	14	33	30	0
41	11	30	27	0
54	14	40	26	0
90	74	16	82	0
62	19	43	31	0
57	25	32	44	0
Mean 59.8				
196 hrs. - 1500 hrs., 16 Aug. - 1900 hrs., 24 Aug. 1961				
83	23	60	28	0
50	14	36	28	0
50	30	20	60	+
50	14	36	28	0
56	17	39	30	0
60	16	44	27	0
52	32	20	62	+
50	31	19	62	0
57	14	43	25	0
54	38	16	70	+
Mean 56.2				
215 hrs. - 1500 hrs., 16 Aug. - 1400 hrs., 25 Aug. 1961				
84	23	61	27	+
54	17	37	31	0
48	11	37	23	0
58	15	43	26	0
58	42	16	72	+
62	40	22	65	0
54	14	40	26	0
62	18	44	29	0
Mean 60.0				

TABLE 21 - Continued

Initial Weight	Des. Wt.	Δ Weight	Percent Original	Viability
240 hrs. - 1500 hrs., 16 Aug. - 1500 hrs., 26 Aug. 1961				
101	29	72	29	0
71	37	34	52	0
70	18	52	26	0
52	36	16	69	0
61	16	45	26	0
67	17	50	25	0
59	15	44	25	0
76	21	55	28	0
Mean 69.6				
265 hrs. - 1500 hrs., 16 Aug. - 1600 hrs., 27 Aug. 1961				
68	19	49	28	0
80	25	55	31	0
64	37	27	58	0
39	12	27	31	0
85	23	62	27	0
87	50	37	57	0
50	24	26	48	0
64	15	49	23	0
64	16	48	25	0
Mean 66.8				
286½ hrs. - 1500 hrs., 16 Aug. - 1330 hrs., 28 Aug. 1961				
58	16	42	28	0
36	11	25	31	0
71	32	39	45	0
68	17	51	25	0
46	12	34	26	0
73	19	54	26	0
46	20	26	43	0
49	13	36	27	0
68	17	51	25	0
57.2				

TABLE 21 - Continued

Initial Weight	Des. Wt.	Δ Weight	Percent Original	Viability
336 hrs. - 1500 hrs., 16 Aug. - 1500 hrs., 30 Aug. 1961				
75	20	55	27	0
81	20	61	25	0
65	51	14	78	+
79	21	58	27	0
70	20	50	29	0
58	16	42	28	0
87	21	66	24	0
52	24	28	46	0
60	15	45	25	0
Mean 69.7				
361½ hrs. - 1500 hrs., 16 Aug. - 1630 hrs., 31 Aug. 1961				
62	16	46	26	0
52	15	37	29	0
58	16	42	28	0
81	23	58	28	0
64	16	48	25	0
64	18	46	28	0
Mean 63.5				
385 hrs. - 1500 hrs., 16 Aug. - 1600 hrs., 1 Sep. 1961				
71	27	44	38	0
52	21	31	40	0
74	22	52	29	0
63	18	45	29	0
75	59	16	79	+
46	11	35	24	0
61	33	28	54	0
43	13	30	30	0
57	14	43	25	0
Mean 60.2				

TABLE 21 - Continued

Initial Weight	Des. Wt.	Δ Weight	Percent Original	Viability
407 hrs. - 1500 hrs., 16 Aug. - 1400 hrs., 2 Sep. 1961				
47	12	35	26	0
42	12	30	29	0
72	19	53	26	0
57	18	39	32	0
48	13	35	27	0
70	11	59	16	0
46	12	34	26	0
61	16	45	26	0
79	19	60	24	0
89	28	61	31	0
Mean 61.1				

TABLE 22

WEIGHT LOSS AND LONGEVITY OF SPHAERIUM OCCIDENTALE IN AN ATMOSPHERE OF 13% RELATIVE HUMIDITY AT 20° C.

(Calculated Vapor Pressure Deficit: 15.27)

Initial Weight	Des. Wt.	Δ Weight	Percent Original	Viability
17½ hrs. - 1630 hrs., 17 Aug. - 1000 hrs., 18 Aug. 1961				
60	56	4	93	+
53	53	0	100	+
50	48	2	96	+
46	38	8	83	+
57	51	6	89	+
74	70	4	95	0
69	64	5	93	+
43	36	7	84	+
51	49	2	96	+
62	60	2	97	+
Mean 56.5			92.3(live)	
25½ hrs. - 1630 hrs., 17 Aug. - 1800 hrs., 18 Aug. 1961				
42	40	2	95	+
59	53	6	90	+
48	44	4	92	+
48	46	2	96	+
69	54	15	78	+
66	60	6	91	+
54	49	5	91	+
45	42	3	93	+
72	69	3	96	+
55	46	9	84	+
Mean 55.8			90.6(live)	
51½ hrs. - 1630 hrs., 17 Aug. - 2000 hrs., 19 Aug. 1961				
72	53	19	74	0
62	43	19	69	+
57	48	9	84	+
70	63	7	90	+
41	33	8	80	+
61	45	16	74	+
62	51	11	82	+
60	44	16	73	+
44	33	11	75	+
58	40	18	69	+
Mean 58.7			77.3(live)	

TABLE 22 - Continued

Initial Weight	Des. Wt.	Δ Weight	Percent Original	Viability
76½ hrs. - 1630 hrs., 17 Aug. - 2100 hrs., 20 Aug. 1961				
64	52	12	81	+
64	54	10	84	+
69	61	8	88	+
46	35	11	76	+
57	31	26	54	0
46	38	8	83	+
53	41	12	77	+
51	34	17	67	+
66	34	32	52	0
61	30	31	49	+
Mean 57.7			75.6 (live)	
100½ hrs. - 1630 hrs., 17 Aug. - 2100 hrs., 21 Aug. 1961				
41	35	6	85	+
48	13	35	27	0
48	22	26	46	+
76	38	38	50	+
51	40	11	78	+
62	49	13	79	+
60	18	42	30	0
49	44	5	90	+
65	31	34	48	+
52	18	34	35	0
Mean 55.2			68.0 (live)	
117½ hrs. - 1630 hrs., 17 Aug. - 1400 hrs., 22 Aug. 1961				
50	41	9	82	+
68	36	32	53	0
49	41	8	84	+
40	11	29	28	0
53	42	11	79	0
69	28	41	41	0
46	28	18	61	0
59	49	10	83	+
64	52	12	81	+
53	26	27	49	0
Mean 55.1			82.5 (live)	

TABLE 22 - Continued

Initial Weight	Des. Wt.	Δ Weight	Percent Original	Viability
142½ hrs. - 1630 hrs., 17 Aug. - 1500 hrs., 23 Aug. 1961				
71	59	12	83	+
40	29	11	73	0
49	28	21	57	+
50	14	36	28	0
44	12	32	27	0
40	34	6	85	+
86	21	65	24	0
62	20	42	32	0
52	25	27	48	+
60	50	10	83	+
Mean 55.4			71.2 (live)	
170½ hrs. - 1630 hrs., 17 Aug. - 1900 hrs., 24 Aug. 1961				
62	51	11	82	+
41	15	26	37	0
69	19	50	28	0
84	30	54	36	0
65	34	31	52	0
58	17	41	29	0
52	16	36	31	0
54	13	41	24	0
88	27	61	31	0
41	11	30	27	0
64	41	23	64	+
Mean 61.6				
189½ hrs. - 1630 hrs., 17 Aug. - 1400 hrs., 25 Aug. 1961				
64	54	10	84	+
53	15	38	28	0
61	27	34	44	0
60	47	13	78	+
67	49	18	73	0
54	14	40	26	0
78	60	18	77	+
66	16	50	24	0
59	31	28	53	0
Mean 62.4				

TABLE 22 - Continued

Initial Weight	Des. Wt.	Δ Weight	Percent Original	Viability
214½ hrs. - 1630 hrs., 17 Aug. - 1500 hrs., 26 Aug. 1961				
81	20	61	25	0
44	12	32	27	0
41	11	30	27	0
54	41	13	76	+
56	41	15	73	+
53	42	11	79	0
78	19	59	24	0
82	34	48	41	0
Mean 61.1				
239½ hrs. - 1630 hrs., 17 Aug. - 1600 hrs., 27 Aug. 1961				
67	18	49	27	0
53	20	33	38	0
55	15	40	27	0
60	15	45	25	0
34	15	19	44	0
44	12	32	27	0
77	20	57	26	0
55	15	40	27	0
62	16	46	26	0
57	14	43	25	0
Mean 56.4				
261 hrs. - 1630 hrs., 17 Aug. - 1330 hrs., 28 Aug. 1961				
57	14	43	25	0
69	19	50	28	0
51	13	38	25	0
41	12	29	29	0
56	37	19	66	0
51	14	37	27	0
62	34	28	55	0
55	47	8	85	+
Mean 55.3				

TABLE 22 - Continued

Initial Weight	Des. Wt.	Δ Weight	Percent Original	Viability
310½ hrs. - 1630 hrs., 17 Aug. - 1500 hrs., 30 Aug. 1961				
63	14	49	22	0
47	12	35	26	0
54	15	39	28	0
44	12	32	27	0
76	21	55	28	0
71	18	53	25	0
41	11	30	27	0
92	40	52	43	0
Mean 61.0				
336 hrs. - 1630 hrs., 17 Aug. - 1630 hrs., 31 Aug. 1961				
38	11	27	29	0
34	23	11	68	+
42	11	31	26	0
34	10	24	29	0
50	14	36	28	0
80	22	58	28	0
48	13	35	27	0
64	17	47	27	0
Mean 48.8				
359½ hrs. - 1630 hrs., 17 Aug. - 1600 hrs., 1 Sep. 1961				
49	14	35	29	0
49	13	36	27	0
42	12	30	29	0
57	15	42	26	0
43	12	31	28	0
50	12	38	24	0
40	18	22	45	0
69	44	25	64	+
43	11	32	26	0
46	12	34	26	0
Mean 48.8				

TABLE 22 - Continued

	Initial Weight	Des. Wt.	Δ Weight	Percent Original	Viability
381½ hrs. - 1630 hrs., 17 Aug. - 1400 hrs., 2 Sep. 1961					
	60	39	21	65	+
	71	17	54	24	0
	39	27	12	69	+
	71	33	38	46	+
	46	9	37	20	0
	69	15	54	22	0
	71	20	51	28	0
	40	11	29	28	0
Mean	58.4				

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